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THE MORPHOLOGICAL VARIABILITY OF *CONVALLARIA MAJALIS* L. IN NATURAL AND CULTIVATED POPULATIONS IN THREE REGIONS OF POLAND

ABSTRACT: Introducing indigenous plants into cultivation and breeding programs in order to obtain new taxa can create the undesirable effects and pose a real threat to natural populations. The main problem of our study was to assess whether the phenotypic characters might allow distinguishing cultivated *Convallaria majalis* from plants occurring in natural habitats.

The range of phenotype variability of *Convallaria majalis* L. shoots from forests and gardens growing in different edaphic factors was studied in 2005–2006 in north (Gdańsk), central (Warsaw) and south (Cracow) regions of Poland. Ten or eleven forest locations and the same number of garden locations were designated in each region. The soil at the forest sites was poorer in phosphorus and calcium and more acidic than at the garden sites from which the cultivated plants were obtained. Thirty flowering shoots were collected from each study site. The numbers as well as size of flowers, size of racemes and leaves were investigated.

The following hypotheses were formulated: (a) due to conscious and unconscious selection, cultivated plants should have more numerous and larger flowers and a longer inflorescence (these characters are most significant for the ornamental appearance of the plant) than plants growing in forests; (b) cultivated plants exhibit less phenotype variability than do natural populations.

The forest plants from all the three regions together had, in comparison with garden plants, significantly shorter racemes with fewer flowers, a narrower and shorter perianth, and a longer lower leaf with a narrower and longer leaf blade. In the forest plants raceme length exhibited the highest variability while the lowest was noted in perianth length. More morphological differences were noted between the forest and garden plants than among those from the three different regions. The results obtained indicate that the level of variability in the studied characters was similar in forest and cultivated plants.

A high level of variability in some morphological characters of lily of the valley probably stems from the high phenotype plasticity of this plant and the diversified biotope conditions in which it occurs. The significant differences between forest and garden plants could have been related to differences in habitat conditions.

KEY WORDS: *Convallaria majalis*, morphological traits, natural habitats, cultivations, soil conditions

1. INTRODUCTION

The consequences of introduction of indigenous plants into cultivation have been studied by many authors. Some studies have confirmed that cultivated plants frequently differ from their protoplasts (e.g. Hammer 1988, Jackowiak 1999). Special attention was paid to the threats imposed by introgressive hybridization of wild plants with their cultivated forms (Jackowiak 1999, Kowarik 1992a, b, Sukopp and Sukopp 1993, Pohl-Orf *et al.* 1998, Galera 2003). It has been found that one of the real threats of introducing indigenous plant species into cultivation is becoming impoverished of natural sites, that occurs when plants are transferred to gardens (Kaźmierczakowa and Zarzycki 2001). Reports have also been made of the irreversible effects of the movement of garden escapees into natural populations (Zemanek 1989, Kowarik 1991, 1992b).

When introducing indigenous plants into cultivation, unconscious selection (leading to narrow the population variability) and especially breeding programs in order to obtain new taxa (in most instances without using reproduction barriers to separate them from the initial species) can have undesirable effects that pose a real threat to natural populations. The problem, how to distinguish spontaneously occurring plants (from natural populations and garden escapees) from cultivated, is an issue that has been addressed in literature for many years (Schouw 1823 after Kronenberg and Kowarik 1989, Galera 2003).

Lily of the valley (*Convallaria majalis* L.) is native to Poland and is under partial protection. It is harvested on a large scale for medicinal purposes and as a cut flower, while its rhizomes are transplanted into gardens. These factors, in combination with intense forest exploitation, have led to the extinction of this species in some locations (Grochowski 1990, Piękoś-Mirkowa and Mirek 2003). The retreat of *C. majalis* in view of human disturbance permits the populations at natural sites to be classified as nonsynanthropic plants (those that avoid habitats under human influence). Lily of the valley is cultivated for perfume as well as ornamental, and medicinal purposes (e.g., Tutin *et al.* 1980, Walters *et al.* 1986, Grochowski 1990, Marcinkowski 2002). Some authors emphasize the fact that the cultivated plants are larger-flowered and more vigorous (Walters *et al.* 1986). Tall plants with especially large flowers are sometimes considered to be a separate taxon – the *C. majalis* cultivar 'Fortin's Giant' (Hay 1972, Griffiths 1997, Hanelt 2001).

C. majalis exhibits a tendency to expand spontaneously outside of its cultivation area (Hegi 1909, Galera 2003, Galera and Sudnik-Wójcikowska 2004). The frequent occurrence of this species at secondary sites (near the cultivation site) has led to the conclusion that this plant is a synanthropic species of the apophyte group (Naegelli and Thellung 1905, cited in Sudnik-Wójcikowska and Koźniewska 1988). This raises the question of whether the spontaneous expansion of *C. majalis* garden escapees is an example of ecological expansion within the natural range of this species, or if this phenomenon should be recognized as the potentially dangerous chorological expansion of selected genotypes of foreign origin. Therefore the following question should be answered: whether variation of the cultivated plants is similar to the variation of plants occurring in natural habitats?

C. majalis occurs primarily in Europe and in some parts of Asia. The species is a synanthropic plant occurring along the east coast of North America where it is quite widely cultivated and subjected to naturalization (Meusel *et al.* 1965, Hultén and Fries 1986). The species has a polymorphic phenotype, within which there are subspecies (or related species) that do not occur in Poland (Komarov 1935, Tutin *et al.* 1980, Czerepanov 1995, Hanelt 2001). However, in natural habitats in Poland, usually within a small area, there are morphological types that differ from one another in the number of flowers in the inflorescence, the shape of the inflorescence, and leaf blade size. The pigmentation of the perianth is also variable as is that of the base of the filaments (Chmiel 1967, Tutin *et al.* 1980). Due to its ornamental value, this species has become the initial form of many garden varieties (Reimann-Philipp 1987, Verron and Le Nard 1993, Griffiths 1997). Although there are several morphologically differentiated horticultural cultivars that reproduce vegetatively (e.g., Phillips and Rix 1991), the most common lily of the valley cultivar does not differ in appearance from wild-growing, typical forms of *C. majalis* (Nowak 2000). It must also be emphasized that in Poland, as is the case in many other countries, the origin of plant material is known only in a very few cases (this type of data are only published for botanical gardens, Galera *et al.* 1999).

The subject of the current study is the phenotype variability of *C. majalis* occurring in natural and garden sites. The following hypotheses were formulated: (a) due to conscious and unconscious selection, cultivated plants should have more numerous and larger flowers and a longer inflorescence (these characters are most significant for the ornamental appearance of the plant) than plants growing in forests; (b) cultivated plants exhibit less phenotype variability than natural populations.

The aim of the study was to compare the range of phenotype variability of forest and garden plants from three geographical regions of Poland taking in consideration edaphic conditions.

2. MATERIAL AND METHODS

2.1. Study sites and collection of plant material

The study sites were located in three regions of Poland: in the north within 100 km of Gdańsk (Gdańsk Pomerania), in central Poland close to Warsaw (Masovian Plain), and in Cracow region (Silesian-Cracow Highlands and Northern Sub-Carpathia, southern Poland). In each region, ten to eleven natural *C. majalis* sites (referred to in the text as forest plants) as well as ten to eleven sites where this plant was cultivated (botanical gardens, allotments, and cemeteries are further referred to as garden plants) were investigated. It also include one sample of *C. majalis* 'Variegata' collected from the Botanical Garden – Center for Biological Diversity Conservation, Polish Academy of Sciences (Powsin near Warsaw)

Garden plants were collected from various cultivation sites that were separated by at least 7 km.The forest study sites were selected using the criterion that *C. majalis* occurrence in dense forest complexes should be located at a minimum distance of 3 km from other sites. Since the annual growth rate of *C. majalis* rhizomes ranges from 20 to 50 cm (Łukasiewicz 1962, Leszczyńska 1969), it was presumed that the minimum distance set between the study sites eliminated the possibility of co-occurrence of garden and forest plants.

Taking into consideration the wide ecological spectrum of the species (Zarzycki *et al.* 2002), in each region where the forest plants were collected, five sites were designated in less fertile and mixed forests and five in mesotrophic deciduous forests. Habitat type was determined based on a map of potential vegetation (Wojterski *et al.* 1980, Chojnacki 1991) and the author's own observations.

In 2005–2006 when *C. majalis* was flowering, 30 generative aboveground shoots were collected from a 1 m wide transect that had been designated at the given sites. This limited the unconscious selection during the collection of the plant samples.

Plants were also obtained from planters that specialize in the propagation and sale of *C. majalis* (referred to further as plants from producers). Four samples from Poland (1 sample of the *C. majalis* cultivar 'Rosea' from a nursery in Łodź and three samples of plants with typical flower and leaf pigmentation purchased in Warsaw, Cracow, and Częstochowa), and two samples from Dutch nurseries (cultivated under special conditions that forces them to bloom in winter) were analyzed.

2.2. Chemical composition of the soil

From each study sites, mixed soil samples from three different locations on the transect at *C. majalis* root level were also collected. The amounts of phosphorus, potassium, and magnesium available to the plants in mg 100g^{-1} (of soil dry weight) were determined with the Egner-Riehm method; total nitrogen (%) was determined with the Kjeldahl method, calcium (w mg dm^{-3}) with spectrophotometer, and water pH with potentiometer (Bednarek *et al.* 2004). The chemical analyses were performed at the laboratories of Regional Chemical Agricultural Stations.

Soil from the forests was more acidic and poorer in phosphorus and calcium than soil from the gardens (P <0.01; Table 1). The pH and nutrient content of the forest soil samples from the three regions did not differ significantly (P> 0.05). The forest soils in each of the three regions were more acidic with less calcium than the garden soils (P <0.001). Soil from the gardens in the Warsaw and Cracow regions did not differ significantly in either nutrient content or pH; however, in the Gdańsk region soil was less acidic and contained more calcium (P <0.01).

2.3. Morphometric studies

Plant's characters chosen for the study were those that impact the ornamental properties of this plant and can be subjected to man-made selection. For each shoot the following were determined: the number of flowers in the inflorescence, scape length, raceme length (from the pedicel base of the lowest flower to the highest flower), leaf blade width (at the widest position) and length, and the length of the lower leaf within 1 mm. Additionally, the following were measured to the nearest 0.1 mm: the length of the pedicel of the lowest flower in the raceme as well as the width and length of the perianth. Measurements were taken immediately following collection on 930 shoots from forest sites, 930 shoots from gardens, and 180 shoots obtained from plantations for a total sample size of 2040 shoots.

2.4. Statistical analysis

The normality of frequency distributions of values was estimated with the Shapiro-Wilk test. The significance of the differences in the mean values of morphological traits was estimated with the t-test. For soil parameters, the differences between samples were tested with the Kruskal-Wallis test. Variability of the values of quantitative characters was estimated with coefficient of variation V (ratio of standard deviation to arithmetic mean expressed in %). One-way ANOVA was used to estimate the differences between the values of the quantitative characters of forest and garden plants and of those from producers and also to compare interregional variation. Spearman's coefficient of correlation (R_s) was used to estimate dependence between the mean values of morphological traits and soil parameters (Łomnicki 2005, Sokal and Rohlf, 1995). All statistical analyses were performed with Statistica 7.1 (StatSoft Inc., 2005).

3. RESULTS

3.1. Inter-regional differences between forest and garden plants

The forest plants from the three regions of Poland differed highly significantly with regard to two characters: raceme length (the longest were noted in the specimens from Warsaw and the shortest were from Gdańsk; arithmetic mean and standard deviation were 54.0±15.8 mm and 46.1±13.8 mm, respectively; P <0.001) and perianth length (the longest were noted in Gdańsk and the shortest in Cracow; 6.1±0.7 mm and 5.6±0.8 mm, respectively; P <0.001; Table 2).

The longest scape (243.3±40.2 mm; P <0.01) and the longest flower pedicel (13.2±3 mm; P <0.001) were noted in the plants from the vicinity of Warsaw, while the lengths of these organs from the plants in Cracow and Gdańsk were similar (arithmetic means ranged from 234 to 235 mm and 11.9 to 12 mm, respectively; Table 2). The diameter of the perianth was the smallest in plants from the vicinity of Cracow (5.9±0.7 mm; P <0.001), while it was similar in the other two regions

Table 1. Soil characteristics of forest and gardens sites.

Soil characteristic	Forests			Gardens		
	N	Mean	Range	N	Mean	Range
pH	31	4.8	3.9–6.3	31	6.8	5.5–7.7
P_2O_5 (mg 100 g^{-1} dw)	31	13.7	2.7–38.3	31	41.4	5.6–173.2
K_2O (mg 100 g^{-1} dw)	31	16.9	2.0–75.0	31	19.9	5.0–56.4
Mg (mg·100 g^{-1} dw)	31	15.4	1.2–124.7	31	10.9	3.0–24.3
N (%)	31	0.33	0.04–1.39	31	0.18	0.02–0.50
Ca (mg dm^{-3})	31	242.7	50.0–1060.0	31	1585.9	298.0–3744.0

Table 2. Morphological differentiation of forest plants of *Convallaria majalis* between north (Gdańsk), central (Warsaw) and south (Cracow) regions of Poland. Arithmetic mean ± standard deviation; results of t-test on P <0.001 (***), P <0.01 (**), and P <0.05 (*) level.

Traits	Gdańsk (gd) N = 300		Warsaw (wa) N = 330		Cracow (cr) N = 300	
	mean	gd-wa	mean	wa-cr	mean	cr-gd
Number of flowers	7.1 ± 1.3	ns	7.2 ± 1.5	ns	7.1 ± 1.7	ns
Scape length (mm)	234.9 ± 37.7	**	243.3 ± 40.2	**	234.1 ± 35.7	ns
Raceme length (mm)	46.1 ± 13.8	***	54.0 ± 15.8	**	50.2 ± 12.8	***
Pedicel length (mm)	11.9 ± 3.1	***	13.2 ± 3.0	***	12.0 ± 3.0	ns
Perianth diameter (mm)	6.6 ± 1.0	ns	6.7 ± 1.2	***	5.9 ± 0.7	***
Perianth length (mm)	6.1 ± 0.7	***	5.8 ± 1.0	**	5.6 ± 0.8	***
Blade width (mm)	49.4 ± 10.4	ns	48.4 ± 10.6	*	50.0 ± 9.6	ns
Blade length (mm)	149.8 ± 23.8	ns	154.1 ± 27.3	**	147.6 ±21.2	*
Leaf length (mm)	288.6 ± 48.0	ns	294.2 ± 56.7	***	279.3 ± 40.2	ns

Table 3. Morphological differentiation of garden plants *C. majalis* between three regions (explanations – see Table 2).

Traits	Gdańsk (gd) N = 300		Warsaw (wa) N = 330		Cracow (cr) N = 300	
	Mean	gd-wa	Mean	wa-cr	Mean	cr-gd
Number of flowers	11.2 ± 2.4	***	9.3 ± 2.4	ns	9.2 ± 2.1	***
Scape length (mm)	237.9 ± 41.6	ns	237.1 ± 37.7	ns	242.0 ± 57.3	ns
Raceme length (mm)	65.5 ± 17.4	***	58.2 ± 16.9	ns	59.2 ± 17.5	***
Pedicel length (mm)	11.9 ± 2.3	ns	12.2 ± 2.7	***	13.5 ± 2.5	***
Perianth diameter (mm)	6.7 ± 0.7	***	7.1 ± 1.4	***	6.7 ± 0.9	ns
Perianth length (mm)	5.0 ± 0.6	***	5.5 ± 0.7	*	5.6 ± 0.6	***
Blade width (mm)	49.2 ± 11.3	ns	50.7 ± 14.0	***	57.8 ± 13.5	***
Blade length (mm)	137.4 ± 23.9	ns	134.9 ± 29.6	***	148.3 ± 33.0	***
Leaf length (mm)	255.3 ± 55.1	*	246.2 ± 50.7	ns	254.6 ± 71.6	ns

(arithmetic means were 6.6 and 6.7 mm). Leaf length was the shortest in plants from the Cracow area forests (279.3±40.2 mm; P <0.05), while in the other two regions it was similar (arithmetic means were 289 and 294 mm). The number of flowers on the shoot (arithmetic mean from 7.1 to 7.2) and the width of the leaf blades (from 48.4 to 50.0 mm) were close to the mean value for the forest plants from all three regions (P> 0.05; Table 2). There was no significant correlation between soil parameters and the mean values of any of the morphological characters.

None of characters analyzed for the *C. majalis* garden shoots differed significantly among any of the three regions studied. Usually, when a given character of the plants in one region was distinctive, then this character was similar in the plants from the other two regions. For example, perianth length was highly significantly different in plants from the Gdańsk vicinity (5.0±0.6 mm) in comparison to plants from the vicinities of Warsaw (5.5±0.7 mm) and Cracow (5.6±0.6 mm; P <0.001; Table 3). The differences between the latter two regions was not significant (P <0.05). Similar situations were noted for other characters such as the number of flowers, perianth diameter, and raceme, pedicel, and leaf blade lengths. It must be emphasized that in garden plants, only scape length was similar in the plants from all three regions (arithmetic means ranged from 237 to 242 mm; Table 3).

3.2. Variability and differences between forest and cultivated plants

In both forest and cultivated (from gardens and producers) plants, the most variable character was raceme length while the least variable was perianth length (Table 4). The analysis of variance indicated greater morphological differentiation between forest and garden plants than among regions (Table 5).

The statistical analysis of all the specimens of forest lily of the valley (from all the three regions) indicated that they had significantly shorter racemes with a fewer number of flowers with narrower and longer perianths and longer lower leaves with wider and longer blades than garden plants (Table 4, Fig. 1A, B). In addition, six samples of lily of the valley from producers in Warsaw, Cracow, Częstochowa, and Łódź were analyzed. Compared to the forest and garden plants, these specimens have the longest raceme and pedicel as well as the shortest scape and the smallest lower leaf (Table 4).

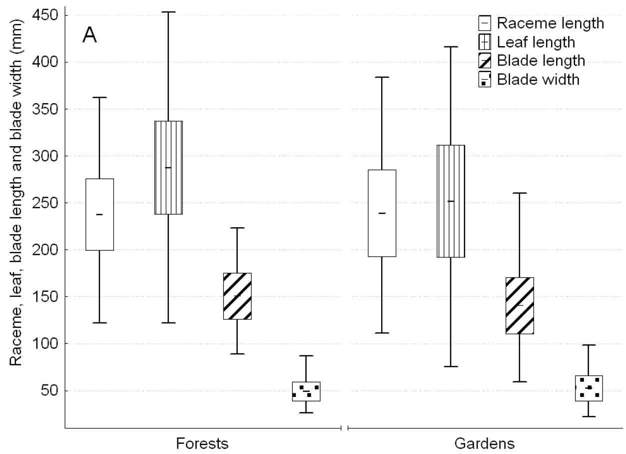
Cultivated plants (from gardens and producers) had a greater number of flowers on larger racemes, shorter and wider perianths, and shorter leaves with shorter blades than plants from forests. However, the plants from producers (in contrast to the garden plants) had narrower leaves, shorter scapes, and longer pedicels than the forest plants. Moreover, plants from producers were distinguished by the greatest variability in scape and pedicel length as well as in leaf width and length (Table 4).

Table 4. Arithmetic mean values and variation coefficient CV (%) for morphological characters of *C. majalis*. Mean values in bold distinguish the significant differences between plants from forests and gardens and gardens and plantations (t-test, P <0.001).

Traits	Forests N = 930		Gardens N = 930		Plantations N = 180	
	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
Number of flowers	**7.1**	21	**9.9**	25	10.0	23
Scape length (mm)	237.6	16	**239.0**	19	**214.1**	27
Raceme length (mm)	**50.2**	29	**60.9**	29	**66.3**	34
Pedicel length (mm)	12.4	25	**12.5**	21	**14.0**	33
Perianth diameter (mm)	**6.4**	16	**6.9**	15	6.6	13
Perianth length (mm)	**5.8**	15	**5.4**	12	5.6	12
Blade width (mm)	**49.2**	21	**52.5**	26	**43.6**	37
Blade length (mm)	**150.5**	16	**140.4**	21	**127.2**	24
Leaf length (mm)	**287.6**	17	**251.9**	24	**211.9**	36

Table 5. Morphological differentiation of forest and garden plants of *C. majalis* among regions: Gdańsk (gd), Warsaw (wa), Cracow (cr) and between forest and garden plants in Poland. ANOVA, P <0.001 (***) and P <0.01 (**).

Traits	Forests (gd-wa-cr)			Gardens (gd-wa-cr)			Forests and gardens		
	df	F	*P*	df	F	*P*	df	F	*P*
Number of flowers	2	1	ns	2	76	***	1	822	***
Scape length (mm)	2	6	**	2	1	ns	1	0.4	ns
Raceme length (mm)	2	24	***	2	16	***	1	204	***
Pedicel length (mm)	2	18	***	2	33	***	1	1.6	ns
Perianth diameter (mm)	2	51	***	2	16	***	1	91	***
Perianth length (mm)	2	36	***	2	80	***	1	131	***
Blade width (mm)	2	2	ns	2	37	***	1	35	***
Blade length (mm)	2	5	***	2	17	***	1	56	***
Leaf length (mm)	2	7	**	2	2	ns	1	198	***



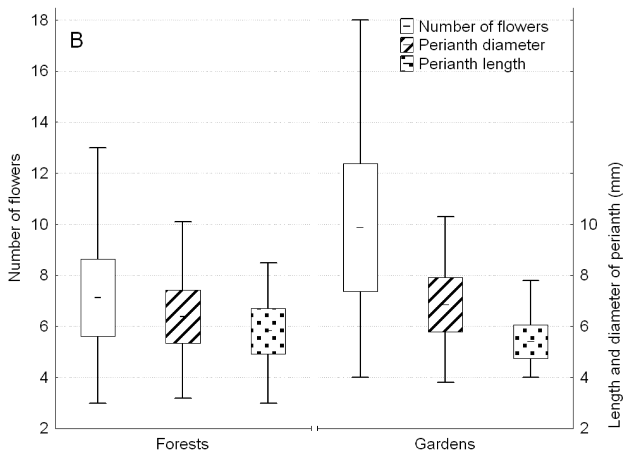


Fig. 1. Variability and significant differences between forest and garden plants for (A) shoot traits, (B) flower traits. Mean, standard deviation and range; t-test, *P* <0.001.

The soil of the forest sites was less rich in phosphorus and calcium and more acidic than that from the gardens (*P* <0.001; Table 1); however, no distinct correlation was noted between the values of the analyzed soil and the mean values of the quantitative characters of lily of the valley. Only the number of flowers was slightly more positively correlated with the pH and calcium content in the garden soil ($R_s > 0.5$; *P* <0.05). It must also be noted that the variability of the fertility and pH of the forest soils was not significant (Kruskal-Wallis test; *P*> 0.05).

4. DISCUSSION

At the beginning of our studies we hypothesized that cultivated plants should differ from those growing in forests on the basis of the morphological traits due to selection. Small but significant morphological differences were found between forest and cultivated plants. Obtained results may indicate that there is a selection in cultivated plants (garden plants and plants from producers) toward increasing the number of flowers on the raceme (which also means longer raceme). Moreover, the flowers of the cultivated plants were shorter, but they had a larger diameter than those of forest plants. This may result from selection (conscious or unconscious) toward spherical or barrel-shaped perianths. Flowers of these shapes are probably more resistant to mechanical damage than the sleek, bell-shaped perianths with straightened tepals. Garden plants and plants from producers have in common shorter leaf blades and shorter stalks than forest plants. This tendency also increases the ornamental value of the lily of the valley since such short leaves do not cover the inflorescence (an important character especially in the case of ornamental flower beds).

An important character of plants used as cut flowers is that their scapes should be as long as possible. The results of morphological studies presented here do not support this thesis. The plants from producers had shorter scapes than both the garden and forest plants. It should also be noted that the length of the scape in the plants from producers exhibited high variability.

The second thesis of the current work assumed that there is greater variability in forest plants as compared to that in cultivated plants. The results obtained indicate that the level of variability in the studied characters was similar in forest and cultivated plants. This could suggest the co-occurrence of forest and garden plants in the studied area or the cross-breeding origin of the plants. The greater variability of the few characters of plants from producers might stem from the more diverse origins of the plant (including specimens not native to Poland). Thus, the results obtained should be interpreted very cautiously since a statistical analysis was performed on a much smaller sample of shoots. A high level of variability in some morphological characters of lily of the valley probably stems from the high phenotype plasticity of this plant and the diversified biotope conditions in which it occurs (Chmiel 1967, Kosiński 1996).

Human impact on the structure of wild *C. majalis* populations stems largely from their exploitation for the collection of raw pharmaceutical material – Herba Convallariae (Gawłowska 1984, Kosiński 2003), the harvesting of flowers, and transplanting of rhizomes to ornamental flower beds. It can be assumed that due to selection, the variability of cultivated lily of the valley will be restricted to vigorous specimens with large and numerous flowers. Anthropogenic selective pressure on natural populations works in the opposite direction since the most decorative flowering shoots are harvested from the site and when rhizomes are transplanted to gardens. This tendency would be more evident in forests near cities (Grochowski 1990). On the other hand, high variability and a still abundant natural population of *C. majalis* might cause selective pressure to be less distinct.

The significant differences between forest and garden plants could have been related to differences in habitat conditions. It can be expected that garden plants have more advantageous site conditions including soil that is more nutrient rich and watered regularly; they receive more sunshine, and there is less competition from other species. Limited flower bed size, however, might lead to increased intraspecific competition. Because of the limited period of the study and the large number of study sites, (31 natural sites, 31 gardens), the habitat analysis in the current paper was restricted to the chemical composition of the soils. In accordance with expectations, the soil collected from gardens was richer in phosphorus and calcium and less acidic than the forest soil samples. However, the size of forest plants was not clearly correlated with the soil parameters analyzed. It is possible that comparison forest and garden plants using the "common garden" method would permit the identification of characters differentiating the plants from these two groups (see e.g., Barnes *et al.* 1998, Freeman and Herron 2001).

The results of statistical analysis of *C. majalis* phenotype variability do not form the basis for genuine delimitation between cultivated and forest plants, because of similar range of variability in both groups. Similar results were reported from studies on morphological evidence that might allow distinguishing wild and cultivated forms of *Pyrus* (Voltas *et al.* 2007).

After morphometric analyses three shoots of *C. majalis* from each population were analyzed by AFLP technique (Chwedorzewska *et al.* 2008). Genetic variability, relatedness and differences between samples were calculated. In contrast to the morphometric results, molecular analyses make it possible to reveal groups of populations according to their geographic origin. However, samples from forest populations and gardens in the same region did not differ significantly from each other, similarly to the morphometric results. Only plant samples from producers formed separate clusters after AFLP analysis.

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