



MORPHOLOGICAL VARIABILITY OF VEGETATIVE ORGANS OF *CAREX SPICATA* HUDS.,  
ORIGINATED FROM DIFFERENT TYPES OF PLANT COMMUNITIES,  
IN EXPERIMENTAL CONDITIONS

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**ABSTRACT.** The variability of the morphological features of vegetative organs of the *Carex spicata* specimens, indicated in prior studies between the populations growing in different plant communities, remains visible and statistically significant also in the conditions of common garden experiment. The observed effect confirms the hypothesis, that the morphological variability is an effect of the genetic differentiation of the studied populations, forming different ecotypes.

**KEY WORDS:** vegetative organs, variability, plant communities, common garden, *Carex spicata*

#### INTRODUCTION

Prickly sedge *Carex spicata* Huds. (Cyperaceae) is one of the most common sedge species in Poland. It is characterized by a distinct morphological variability of vegetative organs depending on habitat conditions and on the type of plant community in which it occurs (VOLLMANN 1903, SZCZEPANIK-JANYSZEK 2001, JANYSZEK 2004). The species tolerate variable habitat conditions and thus it might be a frequent component of different types of plant communities. Therefore *C. spicata* specimens grow in a very diversified soil, moisture and light conditions dependent both on biotope features, plant community structure and type of human pressure to the environment, that is factors which are responsible for development of particular phytocenoses types (SZCZEPANIK-JANYSZEK 2001).

If a particular species occurs in differentiated habitat conditions, it usually modifies its vegetative organs (LOTZ et AL. 1990, SZCZEPANIAK 2002, KRZAKOWA et AL. 2003, ALTSCHULER and SCHIPUNOV 2005). The variability may be explained as a phenotypic effect conditioned by the influence of variable habitat conditions on growth of particular specimens or as a genetically fixed adaptation of particular populations to growth conditions in diversified plant communities. The particular populations of the same species, which grown in variable habitat conditions and are different in respect of the genetically fixed features, might be considered as various ecotypes of the species (MAYR 1974).

In prior studies three distinct morphotypes of *C. spicata* were singled out in natural conditions (JANYSZEK 2004). Distinguished morphotypes were highly correlat-

ed with plant communities where the studied specimens had grown. Thus the main aim of the present study was to investigate if morphological variability of *C. spicata* vegetative organs, grown in three different plant communities, remain stable after the transfer of plants to a **common garden conditions**.

#### MATERIAL AND METHODS

Plant material was sampled from natural sites located in northwestern Poland. There were collected 15 medium sized tufts of *C. spicata* from each of three plant communities, i.e. *Lolio-Plantaginetum*, *Arrhenatheretum elatioris* and *Aegopodium podagraria-Urtica dioica* community (45 in total), where the studied species is very frequent. The plant communities are markedly diversified according to its structure and site conditions they occupied (BRAUN-BLANQUET 1964, MATUSZKIEWICZ 2001). The particular tufts were dug up in September 2002 and all the studied traits were measured immediately with a ruler (0.5 mm accuracy). After measurements, the specimens were planted in the outdoor common garden conditions (horticultural soil, full light, without additional watering). Sedges were planted in 40 × 40 cm spacing in tree blocks. The free spaces between plants were weeded twice in a week during entire growing season to exclude the competition effect on their development. Two years after the establishment of sedges cultivation in experimental conditions (September 2004) all the plants were excavated and the same features as at the beginning of the study were measured.

For the investigation there were chosen the features, which have been indicated as significant for the determination of ecotypes, during prior studies of morphological variability of *C. spicata* (JANYSZEK 2004). The following features of specimen were measured:

- 1) blade width (mm) – (measured in the broadest part of blade),
- 2) blade length (mm),
- 3) number of leaves in a tuft,
- 4) number of stems in a tuft,
- 5) height of the base position of highest leaf blade,
- 6) stem length.

For each investigated *C. spicata* trait, one-factor variance analysis (ANOVA) was applied to show critical differences among plant communities. If critical differences were noted, multiple comparisons were carried out based on Tukey's test for unequal sample sizes. Ward's hierarchical clustering method was used to compute cluster groups of plant communities based on the analysed vegetative traits. Additionally, we compared particular morphological traits of sedges for each plant community and common garden experiment. Statistical analyses were performed using JMP 5.5.1.2. (SAS Institute Inc., Cary, NC, USA; <http://www.sas.com/>).

## RESULTS

The study showed that vegetative organs of *C. spicata* differ significantly in respect to plant community where the plants had grown (natural sites) and the differences among plants are still distinct after specimens transferring to a common garden conditions.

The analysis of material from the natural sites showed, that the specimen growing in carpet community *Lolio-Plantaginetum* are characterized by different set of particular feature values then the plants coming from tall and dense nitrophilous herb communities *Aegopodium podagraria-Urtica dioica* or tall, fertile meadow community *Arrhenatheretum elatioris* (Fig. 1). The plants from *Lolio-Plantaginetum* had short, but broad leaf blades and formed tufts with very large number of short stems with

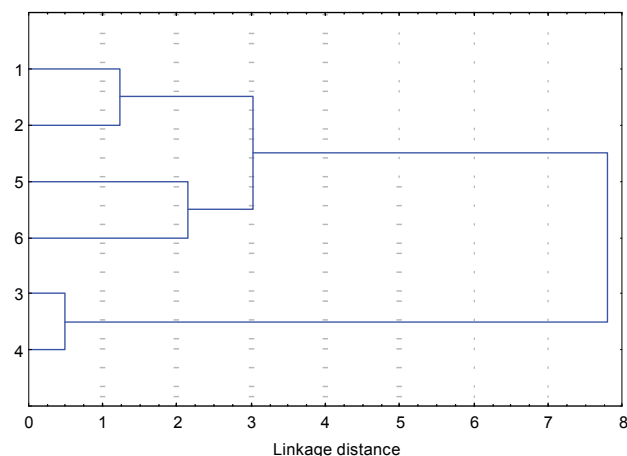


FIG. 1. Dendrogram of cluster groupings of plant communities on the basis of *Carex spicata* vegetative traits for the samples collected in natural sites and common garden conditions. The clustering was made by using Ward's method of agglomeration, with Euclidean distance (x axis). The data were standardized

Explanation of sample numbers (y axis): 1 – *Arrhenatheretum elatioris* (natural sites); 2 – *Arrhenatheretum elatioris* (experiment); 3 – *Lolio-Plantaginetum* (natural sites); 4 – *Lolio-Plantaginetum* (experiment); 5 – *Aegopodium podagraria-Urtica dioica* community (natural sites); 6 – *Aegopodium podagraria-Urtica dioica* community (experiment)

low based leaves, forming a rosette. The main number of leaves and stems in single tuft were in this case much higher, than in a case of plants growing in plant communities of two other types. On the contrary, the sedges growing in mentioned meadow and herb communities formed the tufts with longer, narrower leaf blades, with lowest stem number. The leaves were spread along the stems up to highest level, and their blades were 30-40% longest, than in *Lolio-Plantaginetum*. On the other hand, the leaves of the specimens growing in the *Aegopodium podagraria-Urtica dioica* community were significantly broader than leaves coming from the plants growing in the phytocenoses of *Arrhenatheretum elatioris* (Table 1).

TABLE 1. Ranges (min-max) and mean values ( $\pm$ SE) of investigated *C. spicata* features of plants originated from three different plant communities (natural sites). ANOVAs were performed for all the analysed traits separately. The same letters indicate a lack of statistically significant differences between analysed traits of plants according to Tukey's a posteriori test ( $p < 0.05$ )

Plant community	Blade width (mm)		Blade length (mm)		No of leaves in a tuft		No of stems in a tuft		Height of the highest leaf blade position (mm)		Stem length (mm)	
	min-max	mean ( $\pm$ SE)	min-max	mean ( $\pm$ SE)	min-max	mean ( $\pm$ SE)	min-max	mean ( $\pm$ SE)	min-max	mean ( $\pm$ SE)	min-max	mean ( $\pm$ SE)
<i>Arrhenatheretum elatioris</i>	2-4	2.99 c (0.02)	234-411	334.46 b (1.36)	30-49	35.47 b (1.41)	8-17	12.67 b (0.66)	179-376	261.62 b (1.18)	409-825	576.36 b (3.36)
<i>Lolio-Plantaginetum</i>	3-7	4.86 b (0.02)	111-299	250.84 c (0.91)	44-131	74.93 a (7.50)	16-50	26.80 a (2.97)	18-56	39.47 c (0.38)	199-395	302.17 c (1.29)
<i>Aegopodium-Urtica</i>	4-6	5.05 a (0.03)	196-498	352.35 a (1.77)	30-41	33.20 b (0.81)	11-14	12.33 b (0.29)	200-369	269.76 a (1.43)	399-969	587.95 a (3.42)
ANOVA P > F		0.0000		0.0000		< 0.0001		< 0.0001		0.0000		0.0000

The existence of statistically significant differences between the specimens of *C. spicata* coming from the studied plant communities, was indicated also after two years of cultivation of plants in a homogenous conditions during the common garden experiment (Table 2). As well as for the cases studied *in situ*, there was clearly visible the difference of the of specimens coming from the *Lolio-Plantaginetum* and the specimens originated transplanted from two others plant communities. In a comparison to the plants transplanted from the others

two plant communities, the sedges from *Lolio-Plantaginetum* were still characterized by the highest number of leaves and stems in a single tuft, the very low leaf bases position and the shortest leaf blades.

We found statistically significant influence of habitat conditions (natural sites vs. common garden conditions) on both blade width and length, height of the base position of the highest leaf blade and stem length, comparing plants from all particular plant communities separately (Table 3). Additionally, we found significant differences

TABLE 2. Ranges (min-max) and mean values ( $\pm$ SE) of investigated *C. spicata* features of plants transferred from three different plant communities to common garden conditions. ANOVAs were performed for all the analysed traits separately. The same letters indicate a lack of statistically significant differences between analysed traits of plants according to Tukey's a posteriori test ( $p < 0.05$ )

Plant community	Blade width (mm)		Blade length (mm)		No of leaves in a tuft		No of stems in a tuft		Height of the highest leaf blade position (mm)		Stem length (mm)	
	min-max	mean ( $\pm$ SE)	min-max	mean ( $\pm$ SE)	min-max	mean ( $\pm$ SE)	min-max	mean ( $\pm$ SE)	min-max	mean ( $\pm$ SE)	min-max	mean ( $\pm$ SE)
<i>Arrhenatheretum elatioris</i>	2-4	2.90 c (0.02)	200-391	306.58 a (0.79)	31-53	38.93 b (1.33)	10-17	12.77 b (0.52)	199-299	247.06 a (0.84)	311-740	447.62 a (2.64)
<i>Lolio-Plantaginetum</i>	3-6	4.50 b (0.02)	156-299	262.69 c (0.64)	48-123	71.13 a (6.78)	17-51	26.27 a (2.80)	27-56	42.56 c (0.20)	200-378	292.82 b (0.97)
<i>Aegopodium-Urtica</i>	3-6	4.76 a (0.02)	165-684	280.71 b (1.53)	30-50	36.67 b (1.38)	10-16	11.80 b (0.42)	179-299	232.90 b (0.95)	147-555	446.09 a (1.86)
ANOVA P > F		0.0000		< 0.0001		< 0.0001		< 0.0001		0.0000		0.0000

TABLE 3. Comparison of mean values of *C. spicata* studied features of plants collected in natural sites and cultivated in common garden experiment for three different plant communities. ANOVAs were performed to show the differences among analysed vegetative traits among plants grown in natural conditions and in common garden experiment (natural sites vs. common garden experiment)

Plant community	Vegetative organ traits	Mean value		ANOVA P > F	Tendency (%)
		natural sites	common garden		
<i>Arrhenatheretum elatioris</i>	blade width	2.99	2.90	< 0.0001	-3.0
	blade length	334.46	306.58	< 0.0001	-8.3
	no of leaves in a tuft	35.47	38.93	0.0841	+9.8
	no of stems in a tuft	12.67	12.77	0.9373	+0.8
	height of the highest leaf blade position	261.62	247.06	< 0.0001	-5.6
	stem length	576.36	447.62	< 0.0001	-22.3
<i>Lolio-Plantaginetum</i>	blade width	4.86	4.50	< 0.0001	-7.4
	blade length	250.84	262.69	< 0.0001	+4.7
	no of leaves in a tuft	74.93	71.13	0.7098	-5.1
	no of stems in a tuft	26.80	26.27	0.8969	-2.0
	height of the highest leaf blade position	39.47	42.56	< 0.0001	+7.8
	stem length	302.17	292.82	< 0.0001	-3.1
<i>Aegopodium podagraria-Urtica dioica</i>	blade width	5.05	4.76	< 0.0001	-5.7
	blade length	352.35	280.71	< 0.0001	-20.3
	no of leaves in a tuft	33.20	36.67	0.0386	+10.5
	no of stems in a tuft	12.33	11.80	0.3007	-4.3
	height of the highest leaf blade position	269.76	232.90	< 0.0001	-13.7
	stem length	587.95	446.09	< 0.0001	-24.1

among natural sites and common garden conditions with reference to number of leaves in a tuft of *C. spicata* specimens from *Aegopodium podagraria-Urtica dioica*. Plants transferred from *Arrhenatheretum elatioris* and *Aegopodium-Urtica* community to common garden conditions respond similarly to changes of habitat conditions, i.e. blade length and width as well as height of the base of highest leaf blade and stem length decreased and number of leaves in a tuft increased. Plants transferred from *Lolio-Plantaginetum* to common garden conditions decreased blade width, number of leaves and stems in a tuft and stem length, and increased blade length and height the base of highest leaf blade. Two years after plant transferring to a common garden conditions, the morphological similarity of vegetative organs between plants from particular plant communities (natural sites vs. common garden) is still very distinct (Fig. 1).

## DISCUSSION

The intraspecific differentiation of the morphological traits of plant populations growing in diversified habitat conditions is the frequently observed phenomenon (LOTZ et AL. 1990, PETIT and THOMPSON 1998, SZCZEPANIAK 2002, KRZAKOWA et AL. 2003, JANYSZEK 2004, ALTSCHULER and SCHIPUNOV 2005, HALPERN 2005, GOULART et AL. 2006). When observed on the natural sites, such variability can be interpreted as an effect of existence of genetically determined ecotypes, adapted to specific habitat conditions, or as an effect of phenotypic reaction to the diversified conditions of growth. Less numerous are observations of the keeping of described variability in experimental situations, when the influence of environment on possible modifications of phenotype is excluded, and when it is possible to conclude about genetic basis of observed dissimilarity (DEWEY 1978).

The published studies concern numerous species, and describes the variability of generative organs (FALIŃSKA 1979, KANG and PRIMACK 1991, LONG and JONES 1996, EHLERS et AL. 2002, GOMEZ 2004, HALPERN 2005, LECK and SCHÜTZ 2005, GOULART et AL. 2006), as well as the vegetative ones (LOTZ et AL. 1990, PETIT and THOMPSON 1998, KRZAKOWA et AL. 2003, GARBAY et AL. 2004, JANYSZEK 2004, LAKUŠIĆ et AL. 2005). None of the available publications concerns similar research on *C. spicata*.

Our study showed that *C. spicata* specimens respond to diversified habitat conditions by changing morphological traits of vegetative organs. Both in natural sites and in common garden study plants differed significantly from each other, depending on the plant community where plants had grown. It suggests that the observed morphological variability is genetically based. Therefore, it is possible to conclude, that observed morphological forms have status of ecotypes (MAYR 1974) and the character of observed features has adaptative value in definite habitat conditions in particular plant communities.

The diversity of the studied traits can be connected with the characteristic features of the habitat in plant communities, in which the studied specimen of sedges grew. *Lolio-Plantaginetum* is an open, low carpet community, created usually in effect of pasture or frequent

lawn mowing. In such communities, the competition for light and soil resources is relatively weak, while relatively frequent are irregular, catastrophic disturbances, e.g. massive destruction of leaves or stems. The plants growing in such conditions created low tufts with numerous stems and short, broad leaf blades.

Two other associations are floristically rich, tall plant communities. *Arrhenatheretum elatioris* is a fertile meadow, covering fresh, mesotrophic soils, while *Aegopodium podagraria-Urtica dioica* community is a tall, nitrophilous herb community, covering on fresh soils with a high concentration of nitrogen. The plants from both plant communities formed similar tufts, with small number of long stems, covered by high positioned leaves. The stems of the sedges in *Aegopodium-Urtica* community were somewhat longer. The specimens formed also significantly broader leaves, than the sedges growing in *Arrhenatheretum elatioris*, and their leaf blades had the biggest length to width ratio. Both, the tall stems and the long leaf blades are probably the adaptation to the strong competition for light in a dense, tall plant communities.

The existence of distinctive ecotypes of *C. spicata* is very interesting phenomenon. This species of sedge is common, widespread taxon, and the plant communities being it's habitat are also frequently noted on the territory of Polish lowland. *Carex spicata* is, besides, the anemogamic species. Therefore it is possible to suppose, that for each site of this species there is high probability of the pollination of pollen coming from the specimens growing in all of studied plant communities. The existence of distinctive ecotypes of this, practically panmictic species suggest the existence of unknown, effective processes of selection of seeds or seedlings.

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