The *Carex muricata* aggregate in the Czech Republic: multivariate analysis of quantitative morphological characters

***Carex muricata* agg. v České republice: mnohorozměrná analýza kvantitativních morfologických znaků**

Radomír Ř e p k a

Department of Forest Botany, Dendrology and Typology, Mendel University of Agriculture and Forestry, Zemědělská 3, CZ-613 00 Brno, Czech Republic, e-mail: repka@mendelu.cz.

Řepka R. (2003): *Carex muricata* aggregate in the Czech Republic: multivariate analysis of quantitative morphological characters. – Preslia, Praha, 75: 233–248.

Morphological variation of *Carex muricata* from 232 localities in the Czech Republic was analysed. The plants were preliminarily classified using qualitative characters into six species: *C. contigua*, *C. muricata*, *C. pairae*, *C. chabertii*, *C. divulsa*, and *C. leersiana*. Of 27 quantitative characters, all were used in a principal components analysis and 25 in a discriminant analysis. Both analyses were done using the data for all the species and then separately for the taxonomically complicated species pairs. In the discriminant analysis, the most useful characters for separating particular species were selected; they included the distance between the first and second lowermost spike of the infructescence, infructescence length, glume length in pistillate flower, achene length, length of perigynium beak and spike size. In the classification discriminant analysis, with the six most important characters, 94.4% of plants were correctly classified to the designated groups. The analysis showed that some species pairs (*C. muricata – C. pairae, C. chabertii – C. leersiana*) are only partially distinguished by quantitative morphological characters. Some other species (*C. contigua, C. divulsa*), however, are well differentiated and easily identified.

K e y w o r d s : *Cyperaceae,* discriminant analysis, numerical taxonomy, principal components analysis

Introduction

The *Carex muricata* agg. of the subgenus *Vignea* is considered taxonomically difficult and in need of "comprehensive study throughout its range" (Chater 1980). That these taxa have holocentric chromosomes (with a diffuse centromera) and agmatoploidy (Hartvig 1987) make chromosome counts, a traditional tool of vascular plant taxonomy, less useful. Because of their graminoid nature, they have only a few taxonomically important qualitative characters. Members of the *C. muricata* agg. are generally highly variable, and the variation in most of their quantitative morphological characters overlap. The existence of morphologically intermediate plants, lacking territorial affinity, makes a taxonomic solution difficult and accounts for why the aggregate has never been revised in its entire range. This has resulted in various species concepts being coined and nomenclatural confusion.

For distinguishing particular taxa, earlier authors tended to prefer qualitative characters, such as the structure of the inflorescence (contiguous versus with the lower spikes separated from each other), perigynium shape and its position in relation to the spike axis (divaricate versus erecto-patent) and shape of leaf ligule (length/width ratio).

The most frequent characters used to distinguish the species of this aggregate are presented in Table 1. In my opinion, many of the characters, such as the length of the bract supporting the lowermost inflorescence spike or leaf ligule width/length ratio, are taxo-

Table 1. – Taxonomically important characters of *Carex muricata* agg. used by Central European authors.

Garcke 1885	ligule length and shape of its top distances between the spikes of the inflorescence angle between perigynium and the spike axis structure of infructescence
Appel 1890	achene shape (rhombic, ovoid to obovoid) size and length of perigynium length/width ratio of ligula and colour of ligula margin appearance of stem and leaf colour of plant
Vollmann 1903	angle between perigynia and the spike axis shape of sheath top; hyaline inner face of sheath roughness of stem and stem diameter length and shape of perigynium position of achene in the perigynium; thickness of perigynium wall
Kükenthal 1909	structure of inflorescence and distance between spikes perigynium length corky or spongy tissue at perigynium base angle between perigynium and the spike axis shape of sheath top
Hermann 1943	length/width ratio of perigynium roughness of beak margin angle between perigynium and the spike axis colour of glumes in pistillate flowers inflorescence length leaf width
Schultze-Motel 1977	shape and size of perigynium angle between perigynium and the spike axis
Chater 1980	colour of basal leaf sheaths and colour of roots length/width ratio of ligule corky or spongy tissue at perigynium base inflorescence density (distance between the lower spikes and spike distance/spike length ratio) inflorescence length shape of perigynium base
Dostál 1989	inflorescence density and distance between the lower spikes inflorescence length and branching perigynium length (or length/width ratio) angle between perigynium and the spike axis colour of stem base; colour of sheaths of basal leaves corky or spongy tissue at perigynium base
Fischer 1994	heigth/width ratio of ligule colour of roots roughness of stem leaf width inflorescence length and branching perigynium length gradually or abruptly contracting of perigynium into beak density and structure of inflorescence; distance between the lower spikes glume colour in pistillate flowers

Table 2. – Taxonomic schemes and nomenclature of the *Carex muricata* agg. according to European authors.

This study	Schultz 1871	Ascherson & Graebner 1902	Kükenthal 1909	Chater 1980	Loos 1996
C. contigua Hoppe	*C. contigua* Hoppe	*C. muricata* L.	*C. contigua* Hoppe	*C. spicata* Huds.	*C. spicata* Huds. (s. l.)
C. muricata L.	*C. Pairaei* F. W. Schultz	*C. muricata* subsp. *Pairaei* (F. W. Schultz) Asch. et Graebn.	*C. echinata* Murr.	*C. muricata* L. subsp. *muricata*	*C. muricata* L. (s. str.)
C. pairae F. W. Schultz				*C. muricata* subsp. *lamprocarpa* Čelak.	*C. pairae* F. W. Schultz
C. divulsa Stokes	*C. divulsa* Good.	*C. divulsa* Good.	*C. divulsa* Stokes	*C. divulsa* Stokes subsp. *divulsa*	*C. divulsa* Stokes
C. leersiana Rauschert	*C. Leersii* F. W. Schultz	*C. muricata* subsp. *Leersii* (F. W. Schultz) Asch. et Graebn.	*C. echinata* var. *Leersii* (F. W. Schultz) Kük.	*C. divulsa* subsp. *leersii* (Kneuck.) Walo Koch	C. *guestphalica* (Boenn. ex Rchb.) Boenn. ex O. F. Lang
C. chabertii F. W. Schultz	*C. Chaberti* F. W. Schultz	*C. divulsa* subsp. *Chabertii* (F. W. Schultz) Asch. et Graebn.	*C. divulsa* var. *Chabertii* (F. W. Schultz) Kneuck.	*C. chabertii* F. W. Schultz	

nomically meaningless. On the other hand, the presence of aerenchyma at the perigynium base (often separated from the other part by a groove) is a valuable diagnostic character of *C. contigua* Hoppe, which was not recognized before 1870 (Schultz 1870). The same applies to another useful character, the perigynium shape (Schultz 1868, 1870, 1871). The quantitative characters that came into use later (e.g. Vollmann 1903, Blytt 1906; less Kükenthal 1909 and Hermann 1943) were mainly stem length, leaf width and perigynium length. However, the values were based on measurements made on few plants, and not analysed numerically. Even the accounts in some widely used Central European handbooks (Benkert 1976, Schultze-Motel 1977) were probably compiled using unreliable data in the literature. Only the more recent accounts of the aggregate in Europe (Chater 1980), the British Isles (Jermy et al. 1982, David & Kelcey 1985) and Austria (Fischer 1994) seem to be based on measurements of the most important characters.

Taxonomic schemes and the nomenclature of the aggregate are presented in Table 2. Studies of the species of the aggregate in Europe distinguish three taxa at the species level: *C. contigua* (= *C. spicata* auct.), *C. muricata* L., and *C. divulsa* Stokes, with *C. pairae* F. W. Schultz and *C. leersiana* Rauschert as subspecies of the latter two species, respectively. *Carex chabertii* F. W. Schultz was classified as a local type from Germany (Chater 1980) or a hybrid between *C. divulsa* and *C. leersiana* (David 1976). More recently, it was merged with *C. leersiana* and the name *C. guestphalica* (Boenn. ex Reichenb.) Boenn. ex O. F. Lang was coined for this combined taxon (Loos 1996).

The only paper dealing with the numerical taxonomy of this aggregate contains a biometric study of the *C. muricata* agg. in Slovakia, which uses both qualitative and quantitative characters (Medovič 1960). The characters measured were leaf ligule length and width, inflorescence length and width, distance between the two lowermost spikes of the inflorescence, glume length and width, perigynium length and width, and length of the perigynium beak. For statistical analysis, ratios of some character pairs were also used. Three species comprising five taxa: *C. contigua*, including var. *contigua* and var.

nemorosa, *C. pairaei* auct. (= *C. muricata*) and *C. divulsa*, including two subspecies, subsp. *divulsa* and subsp. *leersii* (= *C. leersiana*) were recognized (Medovič 1960).

The purpose of this study was to analyse quantitative characters in order to answer the following questions: (1) Is it possible to recognize particular taxa (based mainly on qualitative characters) using quantitative characters? (2) Which quantitative characters are most useful for species identification?

Materials and methods

The measurements were made on herbarium specimens. A total of 232 samples were analysed; their localities are listed in Appendix 1. In selecting plants for analysis I tried to (1) cover the whole range of the morphological variation encountered within the aggregate in the Czech Republic and (2) include plants from most parts of the country. To meet the first criterion plants were preliminarily assigned to six taxa (for the purpose of brevity referred to as species) based on qualitative characters, mainly perigynium shape and infructescence structure. Further qualitative characters of particular taxa are presented in Table 3.

Five to ten mature stems in each sample (1–3 plants from a locality) were measured. Twenty-seven characters were analysed: 21 quantitative characters were measured (Table 4) and another 6 characters were calculated as ratios. The characters were always those of one stem and measurements were selected because (1) they were frequently used in identification keys or (2) of personal field and herbarium experience.

The data was analysed by principal components analysis (PCA) using the CANOCO program (ter Braak & Šmilauer 1998). The PCA was used on the correlation matrix, with standardized characters.

The canonical discriminant analysis was computed using the program SPSS 8.0 (SPSS Inc. 1998). First, the entire data set was analysed, and then, taxonomically indistinct species pairs were analysed separately. Characters with the highest coefficient of the canonical structure on the first three canonical functions were selected. These characters explain the highest proportion of variance between groups (species). Than a stepwise discriminant

Table 3. – Qualitative characters in the members of the *Carex muricata* agg. from the Czech Republic.

Species	Characters
C. contigua	root exodermis purple; basal sheaths reddish; sheaths of basal leaves herbaceous (brownish when dry), all with lamina; with corky or spongy tissue at perigynium base
C. muricata	stem below the infructescence rough; glumes markedly shorter than perigynium; dark brown, making at flowering time a strong colour contrast with the green perigynia; early flowering plants
C. pairae	stem below the infructescence smooth; glumes turning hyaline as the fruits mature, making a pronounced colour contrast with dark-brown perigynia (in full fruit maturity); supporting bracts of lower spikes setaceous; later flowering plants; leaf often infested with a pathogenic fungus
C. chabertii	spikes ellipsoid, bristly; perigynium beak pointing backwards (at 20–30° below from the perigynium axis) when mature
C. leersiana	spikes globous; perigynium beak pointing forwards (in the direction of perigynium axis) when mature; infructescence often branched below
C. divulsa	the oldest part of rhizome prolongated; stem below the infructescence sharply rough and trigonous; spikes small, few-flowered, the lower ones sometimes distant from each other; glumes greenish-white

Table 4. – Quantitative characters measured in the present study.

Acronym	Character
Lste	stem length
Wste	stem base width
Wleaf	width of the widest leaf
Lleaf	length of the highest leaf on the stem
Lig	ligula length of the highest leaf
Linf	infructescence length
Winf	infructescence width
Brinf	infructescence branch length
Di12	distance between the 1st and 2nd lowest spikes
Di23	distance between the 2nd and 3rd lowest spikes
Di34	distance between the 3rd and 4th lowest spikes
Spno	number of spikes per infructescence
Spsi	spike size (spike length × spike width)
Perno	number of perigynia per spike
Lglu	glume length in pistillate flower
Lper	perigynium length
Wper	perigynium width
Lbeak	length of perigynium beak (= distance from the top of achene to the apex of perigynium)
Ltoo	length of perigynium teeth
Lach	achene length
Wach	achene width
Lper/Wper	perigynium length/perigynium width
Lach/Wach	achene length/achene width
Lste/Lleaf	stem length/length of the highest stem leaf
Linf/Di12	infructescence length/distance between the 1st and 2nd lowest spike
Lper/Lglu	perigynium length/glume length in a pistillate flower
Lper/Lbeak	perigynium length/length of perigynium beak

analysis was used to find the best set of discriminant characters. In this analysis, characters were entered one by one and the process stopped when none of the remaining characters significantly improved the discriminant capacity ($P \leq 0.01$).

Finally, a classification discriminant analysis (cross-validation) of the samples with the classification function combining respective characters and their weights was carried out to determine the group (taxon) into which the classified object belongs with the highest probability. The procedure was as follows: n – 1 samples were chosen from a set of n samples, and used as the training set. This was used to derive the classification criterion (model), which was then applied to the excluded sample. This was repeated n times.

Results

Principal components analysis

The first three components in the analysis of all samples explained 38.6%, 17.4%, and 10.8% respectivelly of the total variation (Fig. 1). *Carex divulsa* was well separated from the other five species along the second axis, whereas the other taxa were not clearly separated from each other. *Carex muricata* and *C. pairae* were partially separated from the ag-

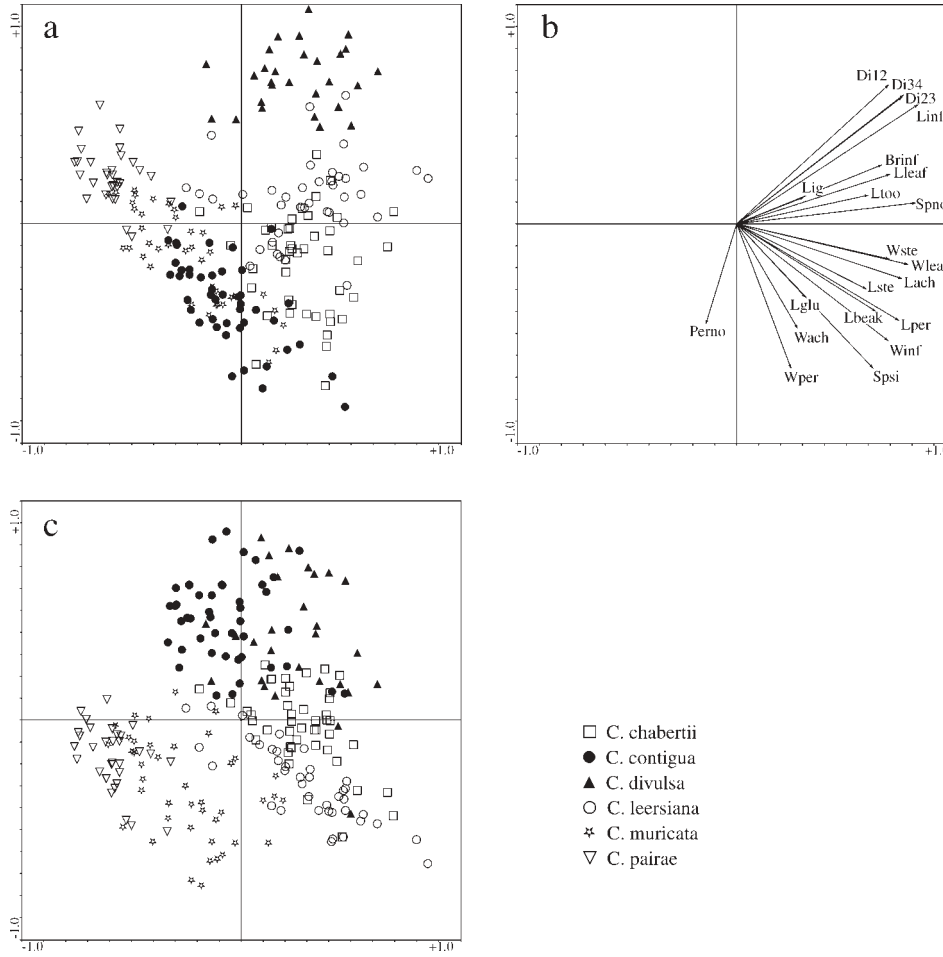

Fig. 1. – PCA ordination of the *Carex muricata* agg. a – axis 1 and 2; b – axis 1 and 2 (the vectors show character loadings); c – axis 1 and 3.

gregate along the third axis. On the other hand, *C. chabertii* and *C. leersiana* overlapped each other along the first three axes.

Separate PCAs (Fig. 2) were calculated for the species pairs poorly separated in the PCA of all the species, i.e. *C. chabertii – C. leersiana*, *C. contigua – C. muricata*, and *C. muricata – C. pairae.* If treated separately, these pairs could be distinguished by quantitative characters used in this study. However, *C. contigua* and *C. muricata* were separated only along the second axis, so the main variation in quantitative characters is not associated with the species.

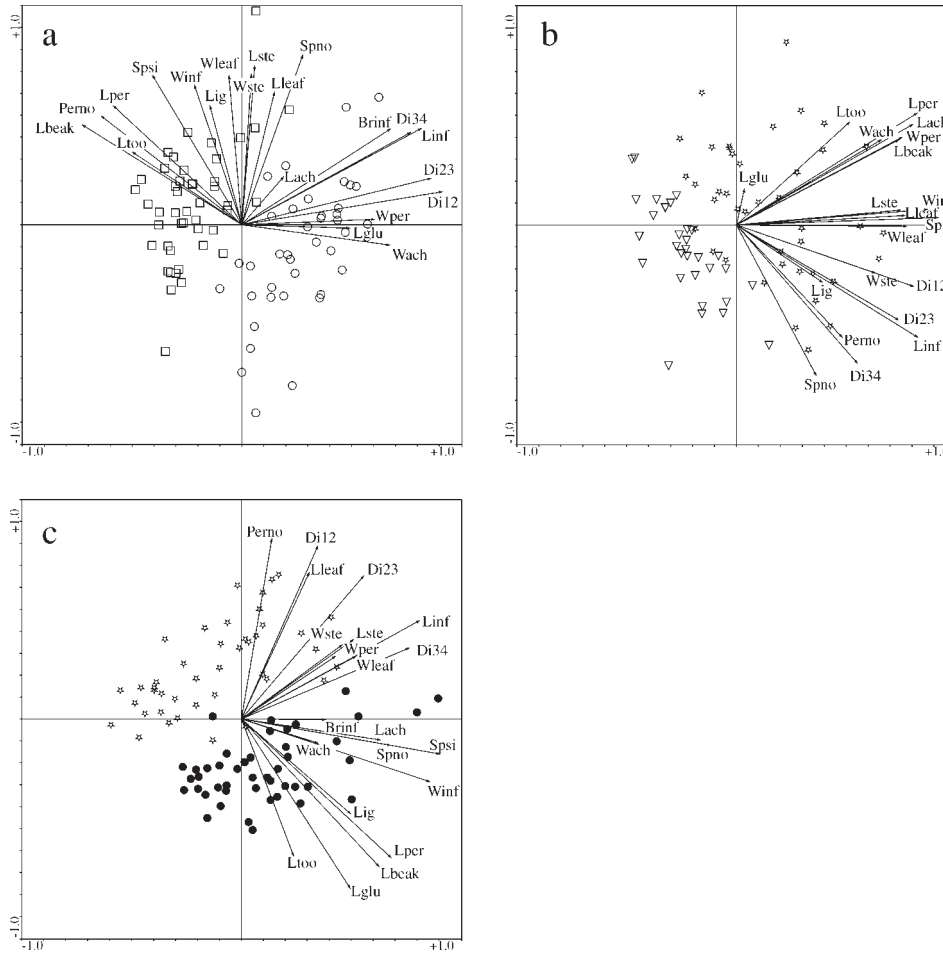

Fig. 2. – PCA ordinations of species pairs in the *Carex muricata* agg. a – *C. chabertii* (□) and *C. leersiana* (○); b – *C. contigua* (●) and *C. muricata* (★); c – *C. muricata* (★) and *C. pairae* (▽).

Discriminant analysis

The correlations between characters were tested uisng the non-parametric Spearman test. High correlations were found for the character pairs Linf and Di23 (0.955, $P < 0.01$), and Linf and Di34 (0.954, $P < 0.01$). For this reason, only Linf, the most important character, was used in discriminant analysis.

In the analysis of the entire data set, the first three canonical functions accounted for 86.3% of the total variation (first 37.6%, second 31.1%, and third 17.6%). The most important characters, according to their correlations with the canonical axes (canonical structure coefficients in absolute value – Table 5), are the distance between the first and second

Table 5. – The most important characters of *Carex muricata* agg. as identified by discriminant analysis. The values of canonical structure coefficients are shown, with significant results shown in bold. See text for details and Table 3 for abbreviations of characters.

Character	Function				
	1	2	3	4	5
Di12	**0.595**	0.072	–0.145	–0.136	–0.042
Linf	**0.589**	0.143	–0.019	–0.073	0.097
Linf/Di12	–0.330	0.224	0.088	0.182	0.159
Lleaf	0.302	–0.068	0.199	–0.022	–0.030
Lach/Wach	0.269	0.007	0.260	0.162	0.183
Ltoo	0.266	0.243	0.263	0.192	–0.036
Lste/Lleaf	–0.213	0.080	0.054	–0.091	0.047
Lglu	–0.072	**0.553**	–0.058	–0.373	0.124
Perno	–0.181	–0.285	0.261	0.077	0.113
Lper	0.149	**0.418**	0.596	–0.147	–0.091
Lbeak	0.113	**0.412**	0.554	0.034	–0.213
Spsi	–0.023	0.165	**0.485**	–0.238	0.140
Winf	0.052	0.156	0.383	–0.219	0.168
Wleaf	0.215	0.071	0.365	–0.194	–0.043
Wste	0.140	0.028	0.258	–0.133	0.029
Lste	0.064	–0.017	0.242	–0.131	0.043
Wper	–0.098	–0.057	0.220	**–0.649**	–0.263
Wach	–0.038	0.029	0.082	**–0.502**	–0.023
Lper/Wper	0.210	0.401	0.286	**0.460**	0.081
Lach	0.221	0.064	0.351	–0.392	0.169
Lper/Lglu	0.036	–0.073	0.118	0.146	–0.005
Spno	0.242	0.121	0.206	–0.122	0.399
Lig	0.050	0.305	–0.076	0.201	–0.330
Brinf	0.210	0.027	0.047	–0.254	0.293
Lper/Lbeak	–0.081	–0.188	–0.245	0.005	0.291

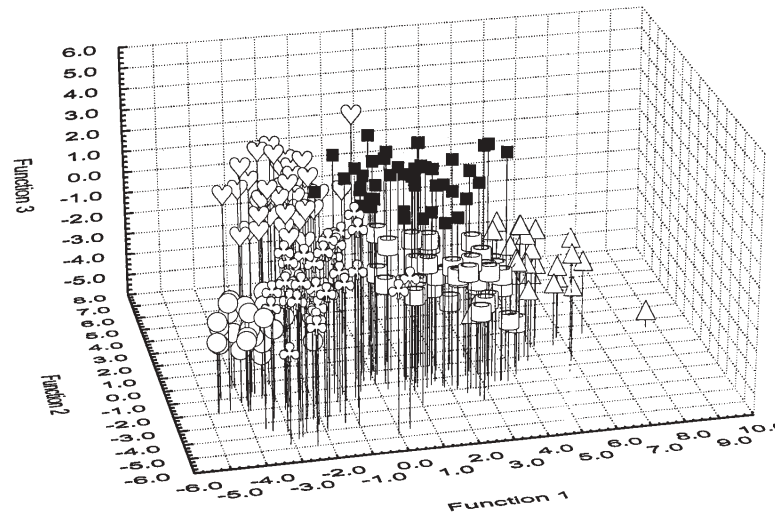

Fig. 3. – Discriminant analysis of the *Carex muricata* agg. Discriminant scores of the first three discriminant functions are shown; ■ – *C. chabertii*, ◯ – *C. pairae*, ♧ – *C. muricata*, ♡ – *C. contigua*, △ – *C. divulsa*, ⛁ – *C. leersiana*.

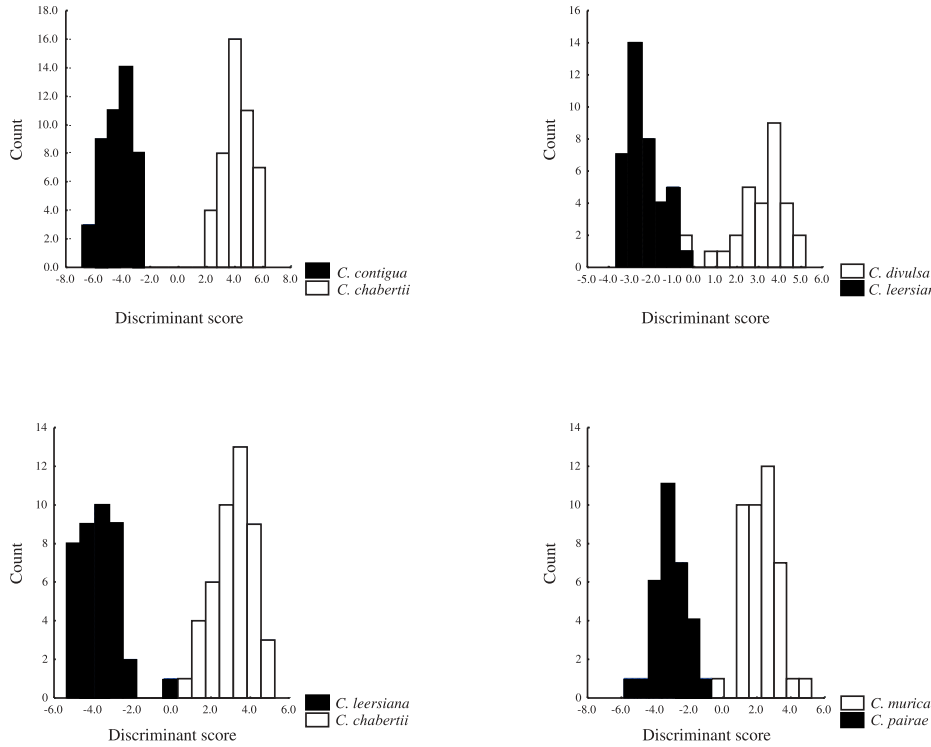

Fig. 4. – Discriminant analysis of selected species pairs of the *Carex muricata* agg.

spike of the infructescence, infructescence length, glume length in pistillate flowers, perigynium length, perigynium beak length and spike size.

Fig. 3 shows samples of particular taxa arranged in the three-dimensional space. According to the first function the best characters for the distinguishing species are the distance between the first and second spike of the infructescence, and infructescence length. According to the second function, the groups are best distinguished by glume length in pistillate flowers, perigynium length and perigynium beak length, and the third function by spike size. The pairs *C. pairae – C. muricata*, and *C. chabertii – C. leersiana* were not fully separated on any of the axes.

Some species pairs were subjected to separate discriminant analysis. The pairs were selected because of (1) frequent confusion in the field and herbaria, (2) separation at infraspecific level in current literature or (3) diagnostic characters unclearly formulated or qualitative. The species pairs analysed included *C. chabertii – C. contigua, C. chabertii – C. divulsa, C. chabertii – C. leersiana, C. chabertii – C. muricata, C. contigua – C. muricata, C. contigua – C. pairae, C. divulsa – C. leersiana, C. leersiana – C. muricata* and *C. muricata – C. pairae.*

Most species pairs were separated along the first canonical axis; they were (most useful characters given in brackets; for character abbreviations see Table 4): *C. chabertii – C. contigua* (Lglu, Lach/Wach, Lper/Lglu, Di12, Lste, Linf), *C. chabertii – C. divulsa* (Perno), *C. chabertii – C. muricata* (Lper/Wper, Lper), *C. contigua – C. muricata* (Lglu), *C. contigua – C. pairae* (Lbeak, Lper) and *C. leersiana – C. muricata* (Linf, Lglu).

Table 6. – The most important characters for species pairs of the *Carex muricata* agg. as identified by discriminant analysis, selected by the value of canonical structure coefficients. See Table 3 for abbreviations of characters.

Species	*C. pairae*	*C. muricata*	*C. chabertii*	*C. leersiana*
	Lbeak	Lglu	Lglu	
	Lper	Lbeak	Lach/Wach	
C. contigua	Lach	Lper/Wper	Lper/Lglu	
	Lglu	Lper	Di12	
	Ltoo	Lper/Lbeak	Lste	
	Wleaf	Lper/Lglu	Linf	
		Wper		
		Lper		
C. pairae		Lbeak		
		Wach		
		Spsi		
		Lste		
			Lper/Wper	Linf
			Lper	Lglu
C. muricata			Spno	Di12
			Lbeak	Wach
			Spsi	Brinf
			Winf	Ltoo
				Lper/Lglu
				Lper/Lbeak
C. chabertii				Lbeak
				Lper
				Linf/Di12
				Di12
			Perno	Wach
			Di12	Lper/Wper
C. divulsa			Linf	Lach
			Spsi	Wach
			Wach	Spsi
			Winf	Lper/Lbeak

The species pairs *C. chabertii* – *C. leersiana* (Lper/Lglu), *C. divulsa* – *C. leersiana* (Wach) and *C. muricata* – *C. pairae* (Lper, Wper, Lbeak, Ltoo) were incompletely separated due to one incorrectly classified sample (Fig. 4).

Stepwise discriminant analysis, run in 16 steps, selected 15 uncorrelated characters for distinguishing between taxa of the *C. muricata* agg. (Table 6). These 15 characters were used in the classification discriminant analysis that classified 97.0% of the samples to the designated assumed groups. When only six of these characters (Di12, Lper, Lglu, Wper, Lig, Perno) were used, 94.4% of the samples were successfully classified, so the other characters increased the percentage very little. The uncorrelated characters useful for distinguishing between particular taxonomically complicated species pairs were also selected by this method (Table 7).

Table 7. – The results of stepwise discriminant analysis. The most important characters for species pairs of the *Carex muricata* agg. are presented. See Table 3 for abbreviations of characters.

Species	*C. pairae*	*C. muricata*	*C. chabertii*	*C. leersiana*
C. contigua	Lbeak Lglu Lig Perno Lste/Lleaf	Lglu Lig Perno Lach Lper/Wper Winf Lste/Lleaf Wleaf	Lglu Wleaf Lig Lleaf Lach/Wach Perno Linf/Di12 Ltoo	
C. pairae		Wper Lbeak Lglu Lach/Wach Linf/Di12		
C. muricata			Lper/Wper Spno Linf/Di12 Spsi Lste Perno	Linf Perno Lglu Lach/Wach Lbeak Wach Lper/Lbeak
C. chabertii				Lper/Lglu Linf/Di12 Wach Lbeak Ltoo Linf Wste
C. divulsa			Perno Linf Lper Brinf	Wper Linf Lbeak Spsi

Table 8. – Results of classification discriminant analysis (cross-validation): 1 – *C. chabertii*., 2 – *C. leersiana*., 3 – *C. divulsa*., 4 – *C. contigua*., 5 – *C. muricata*., and 6 – *C. pairae*.

		Predicted group membership					
		1	2	3	4	5	6
Actual group	1	46=100%	0	0	0	0	0
	2	0	31=100%	0	0	0	0
	3	1=2.4%	1=2.4%	40=95.2%	0	0	0
	4	0	0	0	45=100%	0	0
	5	0	0	0	0	27=93.1%	2=6.9%
	6	0	0	1=2.7%	0	0	38=97.4%

Classification discriminant analysis

Of 232 samples included in classification discriminant analysis, 97.8% were classified correctly, i.e, in accordance with the preliminary classification. As shown in Table 8, one sample of *C. chabertii* was classified as *C. muricata*, one sample of *C. pairae* as *C. muricata*, one sample of *C. muricata* as *C. leersiana*, and two samples of *C. divulsa* as *C. leersiana*.

Discussion

The multivariate analysis of quantitative characters has shown that only *Carex contigua* and *C. divulsa* can be separated from the other members of the aggregate. This is corroborated by the fact that these species are rarely misidentified in the field. The results depend on the method and characters selected.

In PCA, which was used to visualize the differences, some species were poorly separated or unseparated, such as the pair *C. muricata – C. pairae* . These two species can reliably be distinguished by qualitative characters (Jermy et al. 1993, Grulich & Řepka 2002) but not by quantitative characters. Furthermore, intermediate plants are sometimes encountered. The samples of the other complicated species pair, *C. chabertii – C. leersiana*, were well separated along the first axis.

In the classification discriminant analysis (CDA) using 25 characters, 97.8% of the samples were classified correctly. This high success rate supports the value of some quantitative characters. The incorrectly classified samples may represent intermediates and their percentage (2.2%) roughly corresponds to previous estimates (ca 5%).

Comparison of the results of PCA and DA is possible only when comparing species pairs. Most of the differences, however, can be explained by the different algorithms used in the analyses: DA emphasizes characters that distinguish groups while suppressing the variation within groups, whereas PCA tends to accentuate the within-group variation.

The characters identified as important by DA partly coincide with those mentioned in the literature (Table 1). The quantitative characters most frequently used by earlier authors (before 1950) are the perigynium length and width, followed by the distance between the lowermost spikes of the infructescence, inflorescence length, ligule length, ligule length/width ratio and leaf width. Modern authors (Chater 1980, Fischer 1994) mainly use the following characters: distance between the lower spikes in the infructescence (“infructescence density”), perigynium size, ligule length/width ratio, infructescence length, spike distance/spike size ratio. Of the DA characters, the three most frequent and taxonomically most important ones for both groups are the distance between the two lowermost spikes in the infructescence, infructescence length and perigynium length. However, it must be emphasized that the samples originated from the Czech Republic, whereas the literature refers to Central Europe.

Some difficulties arise when identifying *C. chabertii* and *C. leersiana*. Most plants from the Czech Republic are easily identified. They can be distinguished by several quantitative characters if mature or almost mature perigynia are present, but there are few qualitative characters (see Materials and methods). However, intermediates between the two are sometimes found. They are intermediate in length, width, and shape of the perigynium, whereas the remaining characters correspond to *C. chabertii*. Such plants were found at several sites in southern Moravia and northern Bohemia, and they more frequent in southern Slovakia.

Mainly qualitative characters should be used for identification purposes. Quantitative characters, including those of the perigynium, are generally very variable and should be used only as supplementary. It is necessary to measure a particular character on several plants, and to repeat the measurements several times. Identification of some plants, mainly those without fruits or from shaded places, will always be impossible.

The specific rank of *C. leersiana* and *C. chabertii* is uncertain because a well-founded taxonomic solution depends on a study of populations from the whole range of the aggregate.

Acknowledgements

I thank M. Chytrý, J. Danihelka, K. Marhold and P. Šmarda for comments on the manuscript and translation of the text into English, and to Tony Dixon for improving the English.

Souhrn

Článek přináší výsledky analýzy kvantitativních znaků ostřic ze skupiny *Carex muricata*, a to taxonů (druhů) *C. contigua, C. muricata, C. pairae, C. chabertii, C. divulsa* a *C. leersiana*. Celkem bylo studováno 232 vzorků z České republiky (seznam lokalit viz Appendix l), které byly předběžně determinovány podle kvalitativních znaků. Měřeno bylo 27 kvantitativních znaků (tab. 3). Získaný datový soubor byl hodnocen analýzou hlavních komponent (PCA) v programu CANOCO a diskriminační analýzou v programu SPSS 8.0. V obou případech byly analyzovány jak celé datové soubory, tak dvojice taxonů, které jsou pravděpodobně blízce příbuzné nebo působí obtíže při určování.

V analýze hlavních komponent (PCA) celého souboru vysvětlují první dvě osy 38,6 % a 17,4 % variability. Vzorky *C. divulsa* byly odděleny nejlépe, zatímco ostatní taxony byly odděleny nedostatečně. Podle třetí osy, která vysvětluje 10,8 % variability, se vzorky *C. muricata* a *C. pairae* oddělily od zbytku souboru. Dvojice *C. chabertii – C. leersiana* zůstala nerozlišena.

V PCA provedených samostatně pro determinačně obtížné dvojice taxonů se podle kvantitativních znaků hůře oddělila dvojice taxonů *C. muricata – C. pairae,* zatímco dvojice *C. chabertii – C. leersiana* byla oddělena uspokojivě. V druhém případě je však možné rozlišení podle vzdálenosti prvního a druhého dolního klásku plodenství, šířky mošničky, délky plevy samičího květu a šířky nažky.

Diskriminační analýza (DA) celého souboru dat identifikovala šest nejdůležitějších znaků použitelných pro rozlišení jednotlivých taxonů, a to vzdálenost prvního a druhého dolního klásku plodenství, délku plodenství, délku plevy samičího květu, délku mošničky, délku zobánku mošničky a velikost klásku. První tři diskriminační funkce vysvětlily 86,3 % variability. V zobrazení v trojrozměrném prostoru (obr. 3) se alespoň částečně prolínají vzorky taxonů *C. pairae – C. muricata, C. chabertii – C. leersiana* a *C. divulsa – C. leersiana.* Pomocí DA jednotlivých dvojic taxonů byly vybrány nejdůležitější znaky pro jejich vzájemné odlišení. Většina dvojic byla jednoznačně oddělena. Nejednoznačné bylo oddělení dvojic *C. divulsa – C. leersiana*, *C. chabertii – C. leersiana* a *C. muricata – C. pairae.* To odpovídá zkušenostem z terénu a herbářů, kde byly zaznamenány morfologicky intermediární rostliny.

Pomocí krokové diskriminační analýzy bylo vybráno 15 nejvýznamnějších, vzájemně nekorelovaných znaků pro rozlišení taxonů skupiny. Mezi šest nejvýznamnějších patří vzdálenost prvního a druhého dolního klásku plodenství, délka mošničky, délka plevy samičího květu, šířka mošničky, délka jazýčku a počet mošniček v klásku; tyto znaky postačují ke klasifikaci do předpokládaných skupin (taxonů) s úspěšností 94,4 %. Klasifikační diskriminační analýza hodnotila ze 232 vzorků zařazených do analýzy 227 (97,8 %) správně, tj. shodně s předběžnou klasifikací podle kvalitativních znaků.

Mnohorozměrná analýza ukázala, že kvantitativní znaky lze při taxonomickém vymezení a určování zástupců agregátu *C. muricata* použít jako vhodný doplněk kvalitativních znaků. Samostatně však postačují pouze k odlišení některých taxonů, zejména *C. contigua*, popř. *C. divulsa*.

Analýza prokázala jen částečnou rozlišitelnost některých taxonů skupiny *C. muricata* podle zvolených kvalitativních a kvantitativních znaků (*C. muricata – C. pairae, C. chabertii – C. leersiana*). U některých (*C. contigua, C. divulsa*) lze naopak konstatovat, že jsou dobře podle těchto znaků diferencovány a jsou relativně dobře rozlišitelné.

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Received 24 November 2001
Revision received 12 March 2003
Accepted 16 May 2003

Appendix 1. – List of localities studied.

Herbarium specimens given without the name of a collector or without abbreviation of the herbarium institute are deposited in the author's private herbarium. Abbreviations of herbaria follow Vozárová & Sutorý (2001).

Carex contigua Hoppe. W Bohemia: Františkovy Lázně-Lužná, 1996 Lysák; NW Bohemia: Otvice, field road, 1994 Ondráček CHOM; Škrle, saline meadow, 1997 Ondráček CHOM; Vrskmaň, dry meadow, 1994 Ondráček CHOM; NE Bohemia: Mělčany, roadside, 1990 Ondráček CHOM; N Bohemia: Dolní Prysk, Střední vrch Hill, 1994 Ondráček CHOM; Kravaře, meadow, 1993 Ondráček CHOM; Liberec-Kateřinky, embankment in village, 1991 Řepka BRNM; Osečná, embankment in village, 1991 Řepka BRNM; Provodín, Lysá skála Rock, 1997 Ondráček CHOM; Central Bohemia: Lysá nad Labem, meadow, 1994; Orlov, roadside, 1997 Hlaváček herb. Příbram; Velká Černoc, forest margin, 1993 Ondráček CHOM; Žehuň-Stará Báň, road, 1994 Čáp; SW Bohemia: Horažďovice, roadside, 1991; Zelená Lhota, village, 1995; E Bohemia: Dubenec, Zámecký vrch Hill, 1983; Pardubice, Bělobranská dubina forest, 1987 Jozífová; Choceň-Dvořiště, roadside, 1989; Ždírec nad Doubravicí, railway, 1990; Přibyslav, railway station, 1990; Hluboká, pine forest, 1986; S Bohemia: Oslov, Vltava River bank, 1991 Štech; Vráž, roadside, 1991 Štech; Otice, military training area, 1996; N Moravia: Velká Kraš, garden in village, 1997; Jánské koupele, Moravice River valley, 1984; NW Moravia: Ubušínek, Strachův kopec Hill, 1994; Hluboké, meadow, 1994; S Moravia: Lysice, brook valley, 1990; Brno-Židenice, cemetery, 1990; Střelice, Bobrava River valley, 1988; Vedrovice, oak forest, 1988; Hrušovany u Brna, oak forest, 1990; Moutnice, Rumunská bažantnice forest, 1989; Pohořelice, Proklatá forest, 1990; Mikulov, Milovický les forest, 1989; Tvrdonice, Morava River valley, 1985; Malínky, oak-hornbeam forest, 1992; SE Moravia: Osvětimany, Vranovy žleby valley, 1987; Buchlovice, Chrastí Hill, 1987; Hodonín, Dúbrava forest, 1990; Hodonín town, 1989; Central Moravia: Hustopeče nad Bečvou, roadside, 1985; E Moravia: Hradčovice, field roadside, 1987 Danihelka.

Carex muricata L. W Bohemia: Pavlovice, Mže River valley, 1992 Štech; NW Bohemia: Místo, vicinity of castle ruin, 1996 Ondráček CHOM; Liboňov, in vicinity of the village, 1997 Ondráček CHOM; Vysoká Pec, Jedlák Hill, 1996 Ondráček CHOM; Stadice, Hradiště reserve, 1996 Ondráček CHOM; N Bohemia: Česká Lípa, east limits of town, 1997 Ondráček CHOM; Bezděz, beech forest, 1998; Central Bohemia: Orlík, broadleaved forest, 1991 Marek; Světlá nad Sázavou, railway, 1997; Tunochody, forest road, 1997 Lysák; Vlastějovice, quarry, 1997 Grulich; SW Bohemia: Kašperské Hory, on a wall, 1996; Srní, forest margin, 1996; Čeňkova Pila, Dračí skály rock, 1995; Filipova Huť, roadside, 1995; S Bohemia: Oslov, Vltava River bank, 1991 Štech; Záhvozdí, Knížecí Stolec Mountain, 1996; Černá v Pošumaví, quarry, 1996; NE Bohemia: Dobré, brook valley, 1997; Osečnice, Klečkov castle ruin, 1997; Machov, roadside, 1997; NW Moravia: Korouhvice, oak-hornbeam forest, 1994; Veselí, mixed forest, 1994; S Moravia: Milonice, beech forest, 1986; Hořice, mixed forest, 1986; Blansko, roadside, 1992; Čebín, Čebínka Hill, 1990; Horákov, Rokytnice brook valley, 1992; Hrušovany u Brna, black locust forest, 1990; Žabčice, Scot's pine plantation, 1986; Pohořelice, Proklatá forest, 1990; Hlína, in vicinity of village, 1986; Neslovice, brook valley, 1985; Ivančice, St. Jakub Hill, 1996; Moutnice, Rumunská bažantnice forest, 1989; Dolenice, Libické forest, 1991; Podmolí, Liščí skála Rock, 1992; Uherčice, castle park, 1997; Snovídky, Hluboká valley, 1986; SE Moravia: Salaš, roadside, 1987; Košíky, Kudlovická dolina valley, 1985; Hodonín, Dúbrava forest, 1992.

Carex pairae F. W. Schultz. N Bohemia: Velký Šenov, Partyzánský vrch Hill, 1997; Vysoká Lípa, in village, 1998 Čáp; Vysoká Lípa, roadside, 1994 Ondráček CHOM; Dlouhý Důl, pasture, 1997 Čáp; Dolní Prysk, roadside, 1994 Ondráček CHOM; Kateřinky, roadside ditch, 1991; Doksy, Borný Hill, 1997 Ondráček CHOM; Hradčany, roadside, 1997 Ondráček CHOM; NW Bohemia: Libouchec, meadow, 1998 Ondráček CHOM; Petrovice, pasture, 1997 Ondráček CHOM; Nakléřov, meadow, 1998 Ondráček CHOM; Habartice, roadside, 1998 Ondráček CHOM; Unčín, under Kyšperk castle, 1998 Ondráček CHOM; Vysoká Pec, Jedlák Hill, 1996 Ondráček CHOM; Pyšná, forest margin, 1995 Ondráček CHOM; Chomutov-Horní Ves, oak forest, 1997 Ondráček CHOM; Domina, railway, 1998 Ondráček CHOM; Blahuňov, pasture, 1995 Ondráček CHOM; Petlery, roadside, 1993 Ondráček CHOM; Kamenné, meadow, 1996 Ondráček CHOM; SW Bohemia: Nýrsko, Hraničář Hill, 1995; Divišovice, Divišovický les forest, 1995; Zelená Lhota, on a wall, 1995; Javorná, forest margin, 1995; Červená, vicinity, 1996; Rejštejn, dry balks, 1995; Nicov, dry balks, 1996; Přední Zborovice, pasture, 1991 Otruba; Central Bohemia: Ronov, Sázava River valley, 1990; Nové Dvory, railway dike, 1986; NE Bohemia: Olešnice v Orlických horách, pasture, 1997.

Carex chabertii F. W. Schultz. NW Bohemia: Horní Kaff, meadow, 1993 Ondráček CHOM; Otvice, oak forest, 1994 Ondráček CHOM; Údlice, Údlické doubí forest, 1994 Ondráček CHOM; Pesvice, Michanický lesík forest, 1994 Ondráček CHOM; Lideň, pasture, 1994 Ondráček CHOM; Petlery, quarry, 1993 Ondráček CHOM; Central Bohemia: Římovice, a clearing in mixed forest, 1997; NE Bohemia: Bezděkov nad Metují, roadside, 1997; Machov, dry meadow, 1997; Nový Hrádek, Frymburk castle ruin, 1997; Olešnice v Orlických horách, in the

village, 1997; Olešnice, Vápenka quarry, 1997; NE Moravia: Karolinka, forest road, 1997 Hájek BRNU; Central Moravia: Chropyně, Rasina forest, 1985; Plešovec, hard-wood floodplain forest, 1985; S Moravia: Pustiměř, black locust forest, 1993; Drysice, oak-black locust forest, 1993; Pozořice, in a vicinity of cement factory, 1999; Česká u Brna, Sychrov Hill, 1986; Bílovice, Melatín brook valley, 1985; Bílovice, oak-hornbeam forest, 1999; Brno-Obřany, Svitava River valley, 1999; Omice, mixed forest, 1985; Střelice, Střelický les forest, 1985; Hlína, brook valley, 1986; Ivančice, black locust forest, 1986; Rešice, Rokytná river valley, 1985; Dobřínsko, dry meadow, 1985; Čermákovice, oak forest, 1985; Džbánice, Tanárka forest, 1986; Vémyslice, oak-black locust forest, 1985; Petrovice, black locust forest, 1999; Lesonice, black locust forest, 1985; Lesonice, Lesonický les forest, 1986; Vedrovice, Krumlovský les forest, 1986; Trstěnice, black locust forest, 1986; Božice, U Jezírek valley, 1986; Moutnice, Rumunská bažantnice forest, 1984; Přibice, Bedřichův les forest, 1985; Ladná, roadside, 1985; Valtice, Boří les forest, 1985; Kobeřice, forest valley, 1985; Mutěnice, Dolní Kapánsko forest, 1999; Ratíškovice, Rúdník hamlet, 1985; Moravský Písek, Chladíkov forest, 1986; SE Moravia: Kostelany, roadside, 1985.

Carex leersiana Rauschert. Central Bohemia: Velcí, military training area, 1999 Nesvadbová et Pecháčková PL; Loučeň, in the vicinity of Nový pond, 1983 Šachl ROZ; Přibyslavice, Tisá skála rock, 1997; S Moravia: Lysice, castle park, 1990; Luleč, in the vicinity of a quarry, 1992; Vítovice, gamekeeper's house, 1992; Brno-Černovice, roadside ditch, 1984–5; Hrušovany u Brna, black locust forest, 1990; Rakšice, oak forest, 1988; Vedrovice, Krumlovský les forest margin, 1988; Bohutice, Leskoun Hill, 1999; Podmolí, place called Šóbes, 1993; Moutnice, Rumunská bažantnice forest, 1989; Valtice, Boří les forest, 1990; Charvátská Nová Ves, Ladenská alej road, 1990; Poštorná, along the railway, 1995; Poštorná, Boří les forest, 1995; Kobeřice u Brna, thermophilous oak forest, 1994; Hlubočany, Hlubočanský háj forest, 1993; Nemochovice, Hradisko Hill, 1994; Nevojice, Černecký hájek forest, 1994; Nevojice, forest clearing, 1994; SE Moravia: Ždánice, beech forest, 1996; Ždánice, place called U Slepice, 1996; Lovčice, beech forest I, 1996; Lovčice, beech forest II, 1996; Snovídky, brook valley, 1996; Mouchnice, brook valley, 1996; Jestřabice, Hradisko Hill, 1996; Jestřabice, Kyjovka River valley, 1996; Bohuslavice, Hradisko Hill, 1996; Bohuslavice, orchard, 1992; Vřesovice, brook valley, 1992; Osvětimany, beech forest, 1992; Osvětimany, forest margin, 1992 Buchlovice, in the vicinity of Buchlov castle, 1987; Salaš, Brdo Hill, 1987; Salaš, place called Pod Brdem, 1987; Kostelany, roadside, 1985; Hodonín, in the town, l990; Hodonín, Dúbrava forest, 1988.

Carex divulsa Stokes. Central Moravia: Uherčice, Horní les forest, 1996; E Moravia: Holešov, castle park, 1961 Zavřel BRNM; Ondřejovsko, beech forest, 1927 Staněk BRNM; S Moravia: Bohuslavice, deciduous forest, 1960 F. Šmarda BRNM; Mutěnice, Dolní Kapánsko forest, 1992; Mutěnice, oak-hornbeam forest, 1999; Dolní Bojanovice, Prostřední Kapánsko forest, 1992; Dolní Bojanovice, Zlodějský háj forest, 1992; Lednice, Lubeš gamekeeper's house, 1990; Břeclav, Kančí obora forest, 1990; Břeclav, hard-wood floodplain forest, 1990; Břeclav, forest clearing, 1990; Břeclav, oxbow, 1982; Lanžhot, in the vicinity of Pohansko, 1990; Lanžhot, in the vicinity of Barvínkový hrúd, 1990; Lanžhot, in the vicinity of Dlouhý hrúd, sand elevation 1990; Lanžhot, in the vicinity of the Cahnov reserve, 1994; Lanžhot, hard-wood floodplain forest, 1995; SE Moravia: Salaš, Salaška valley, 1987; Kunovice, Zápověď forest, 1986; Tvarožná Lhota, Vrbecké rubanice forest, 1946 Müller BRNU; Súchovské Mlýny, oak-hornbeam forest, 1999; Javorník, Kamenná vrata Mountain, 1957 F. Šmarda BRNM; Vápenky-Lesná, beech forest, 1942 Staněk BRNM; Starý Hrozenkov, Vlčí Důl valley, 1931 Podpěra BRNU.