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Multivariate Morphometric Study of the *Bromus erectus* Group (*Poaceae – Bromeae*) in Slovenia.

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With 6 Figures

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Summary

BAČIČ T. & JOGAN N. 2001. Multivariate Morphometric Study of the *Bromus erectus* Group (*Poaceae – Bromeae*) in Slovenia. – Phyton (Horn, Austria) 41 (2): 295–311, 6 figures. – English with German summary.

Since the end of the 19th century, six species from the *Bromus erectus* group have been recorded for Slovenia: *B. erectus* HUDSON s.str., *B. transylvanicus* STEUDEL, *B. condensatus* HACKEL, *B. stenophyllus* LINK, *B. pannonicus* KUMMER & SENDTNER and *B. moellendorfianus* (ASCHERSON & GRAEBNER) HAYEK. Since the delimitation of the taxa is still unclear, the purpose of the research was to investigate the discriminative power of distinguishing characters, used in various floristic works and also some new potentially useful distinguishing characters, subsequently to confirm whether these taxa really occur in Slovenia and finally to state their distribution. Besides the classical 'intuitive' approach to this problem, some methods of numerical taxonomy were used. The study was based on material from the herbarium LJU and second author's private collection. In the analysis 198 individuals were taken into account and 48 characters were investigated. The data were analyzed using hierarchical clustering and ordination methods (principal coordinate analysis, discriminant analysis) as well as some univariate statistical methods.

The results of the analysis confirm the occurrence of *B. erectus* s.str., *B. transylvanicus* and *B. condensatus* in Slovenia. The three taxa mainly differ in (1) the type of pubescence of the leaf-sheaths, leaf-blades and margins, (2) the ratio of the length of spikelet to the length of the shortest branch in the lowest panicle node and (3) the

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ratio of the number of primary panicle branches, shorter than their spikelets, to the number of all primary panicle branches. *B. transylvanicus* and *B. condensatus* proved very similar and their occurrence can be explained as ecogeographical vicariism: *B. transylvanicus* is a mountain taxon, mostly of the Alpine, Dinaric and Prealpine phytogeographical region; *B. condensatus* is predominantly a lowland species and can be found in South-Western (the Coastal region) and Central part of Slovenia. *B. erectus* s. str. is distributed from lowlands to subalpine belt and is widespread all over the territory.

The occurrence of *B. pannonicus* and *B. moellendorfianus* remains unconfirmed. The first one can be expected in the most continental eastern parts of Slovenia, while the occurrence of the second one is very questionable, as it has been hitherto known only in Central Bosnia. The reports of *B. stenophyllus* in Slovenia seem to be based on misidentification of *B. transylvanicus* material.

Zusammenfassung

BAČIČ T. & JOGAN N. 2001. Multivariate morphometrische Studie der *Bromus erectus*-Gruppe (*Poaceae – Bromeae*) in Slowenien. – Phyton (Horn, Austria) 41 (2): 295–311, 6 Abbildungen. – Englisch mit deutscher Zusammenfassung.

Seit dem Ende des 19. Jahrhunderts sind sechs Sippen der *Bromus erectus*-Gruppe für Slowenien angegeben worden: *B. erectus* HUDSON s.str., B. *transylvanicus* STEUDEL, *B. condensatus* HACKEL, *B. stenophyllus* LINK, *B. pannonicus* KUMMER & SENDTNER und *B. moellendorfianus* (ASCHERSON & GRAEBNER) HAYEK. Weil die Abgrenzung der einzelnen Arten noch unklar ist, war es Zweck dieses Forschungsprojekts, die Aussagefähigkeit verschiedener Unterscheidungsmerkmale zu prüfen, sowohl solcher, die in verschiedenen botanischen Arbeiten verwendet wurden, als auch einiger aus eigenen Beobachtungen. Darüberhinaus war unser Ziel, zu überprüfen, ob diese Taxa in Slowenien wirklich vorkommen, und schließlich ihre Verbreitung anzugeben. Außer dem klassischen „intuitiven" Zugang zu diesem Problem wurden einige Methoden der numerischen Taxonomie angewendet. Die Studie beruht auf Material aus dem Herbarium LJU und dem Privatherbar des Zweitautors. In die Analyse wurden 198 Individuen einbezogen und 48 Merkmale untersucht. Die Daten wurden durch Clusteranalyse und Ordinationsmethoden (Hauptkoordinatenanalyse, Diskriminanznanalyse) sowie durch einige univariante statistische Methoden analysiert. Die Ergebnisse der Untersuchung bestätigen die Vorkommen von *B. erectus* s.str., *B. transylvanicus* und *B. condensatus* in Slowenien. Die drei Taxa unterscheiden sich hauptsächlich in (1) der Behaarung von Blattscheiden, Spreiten und Rändern, (2) dem Verhältnis von Länge der Ährchen zu Länge des kürzesten Rispenastes am untersten Rispenknoten und (3) dem Verhältnis von Zahl der primären Rispenäste, die kürzer als ihre Ährchen sind, zur Gesamtzahl der primären Rispenäste. *B. transylvanicus* und *B. condensatus* sind sich sehr ähnlich und ihr Vorkommen kann durch ökogeographische Vikarianz erklärt werden: *B. transylvanicus* ist eine Berglandsippe, die meist im alpinen, dinarischen und praealpinen phytogeographischen Gebiet vorkommt, während *B. condensatus* vorwiegend eine Tieflagenspezies ist und im Südosten (Küstenland) und Zentrum Sloweniens gefunden werden kann. *B. erectus* s.str. wird vom Tiefland bis zur subalpinen Höhenstufe angetroffen und ist in ganz Slowenien weit verbreitet.

Das Vorkommen von *B. pannonicus* und *B. moellendorfianus* wird nicht bestätigt. Ersterer könnte in den kontinentalen, östlichen Teilen Sloweniens jedoch erwartet werden. Das Vorkommen der zweiten Art ist dagegen fraglich, da diese bisher nur in Zentralbosnien bekannt ist. Die angegebenen Vorkommen von *B. stenophyllus* in Slowenien beruhen auf falsch bestimmtem *B. transylvanicus*-Material.

1. Introduction

In the last revised edition of Hegi's Ilustrierte Flora von Mitteleuropa, CONERT 1996: 734–735 noticed the poor knowledge of the *Bromus erectus* group (*Poaceae – Bromeae*) on the southern fringe of the Alps and adjacent regions. It is still based mainly on the account of the taxa related to *B. erectus* by HACKEL 1879: 205–211. The lack of recent investigations and blurred limits between the microspecies of *Bromus erectus* group are the reasons why many authors consider all taxa of the group only as *B. erectus* 's.lat.'. Since the precise delimitation of the microspecies remains unclear, chorological, ecological and phytosociological investigations can not be carried out. However, there is an urgent need for such work, since *Bromus erectus* s.lat. is a very important grassland species from the phytosociological and agronomic point of view. Semi-natural dry grasslands (Festuco-Brometalia) are also very valuable in nature conservation.

Until recently, besides the widespread species *B. erectus* HUDSON s.str., 5 taxa from the *B. erectus* group have been recorded for Slovenia: *B. transylvanicus* STEUDEL (HACKEL 1879: 207, PAULIN 1936 in schedis, sec. WRABER 1966: 140), *B. condensatus* HACKEL (POSPICHAL 1897: 126), *B. pannonicus* KUMMER & SENDTNER (CONERT 1997: 737), *B. moellendorfianus* (ASCHERSON & GRAEBNER) HAYEK (PETROVA & al. 1993: 186) and *B. stenophyllus* 'LINK' (FLEISCHMANN 1844: 14, PAULIN 1936 in schedis, sec. WRABER 1966: 140). CONERT 1996: 735 mentioned the name *B. stenophyllus* LINK, but it is not considered in his treatment of the *B. erectus* group. SMITH 1980: 185 in Flora Europaea treats the majority of the discussed taxa (including *B. stenophyllus*) at the level of subspecies, but considers *B. moellendorfianus* and *B. pannonicus* as separate species, the latter with two subspecies, subsp. *pannonicus* and subsp. *monocladus*. By his opinion, *B. erectus* subsp. *condensatus*, *B. erectus* subsp. *stenophyllus*, *B. erectus* subsp. *transsilvanicus* and *B. pannonicus* subsp. *pannonicus* occur in the southern fringe of the Alps and adjacent regions.

The aim of the study was to confirm or refute the occurrence of all these taxa in Slovenia, to state their distribution and also to find out how efficiently can the already known distinguishing characters and some new potentially distinguishing characters delimit the taxa. Besides the classical approach to this problem, i.e. revision of herbarium material, using keys and floras, some methods of numerical taxonomy were also applied. The results of the morphological study should represent a firm basis for subsequent thorough investigations including other sources of taxonomic evidence.

The studied taxa differ also in chromosome numbers: the counts for *B. erectus* s.str. are 2n=42 and 2n=56 (as reported in CONERT 1996: 733), for *B. transylvanicus* 2n=56 (LÖVE & LÖVE 1964: 74) and for *B. pannonicus* 2n=28 (CONERT 1997: 737). Further studies of this group should therefore indispensably include karyology, which was beyond the scope of the present study.

2. Material and Methods

2.1. Origin of the Material

The present study is based on herbarium material from herbarium LJU and from second author's private collection (accessible upon request). The plants were collected from various localities in Slovenia. From each herbarium sheet one well developed and completely collected plant was randomly chosen for the morphometric study to serve as an operative taxonomic unit (OTU). The chosen plants were marked with the OTU number. All together, there were 198 OTUs included in the study. The full documentation of the OTU's (OTU localities, the matrix with all the measured or scored characters for each OTU, preliminar and final determinations ...) is deposed at the library of the Department of Biology (Biotechnical Faculty, University of Ljubljana), as a part of graduation thesis 'Taxonomy and Chorology of Bromus erectus agg. in Slovenia' of the first author under supervision of univ. prof. dr. Tone WRABER. The list of OTUs is available upon request from the corresponding author.

2.2. The Studied Characters

A list of 48 characters, presumed to reflect the taxonomic differences, was prepared. Among them there were some characters described as discriminative by several authors (HACKEL 1879: 204–210, CONERT 1996–97: 710–757, SMITH 1980: 185, MELZER 1981: 119–120, ASCHERSON & GRAEBNER 1901: 580–589) as well as some new characters, which turned out to be potentially useful during the preliminary revision of the material. The following characters were measured or scored:

Binary characters:

1. SHT.prs – the persistency of the tiller leaf-sheaths
   (0 – the leaf-sheaths of the tillers eventually decaying into parallel fibres; 1 – leaf-sheaths remaining intact when dead)
2. UPLF.pub – the type of pubescence of the upper leaf-blade surface of the tiller
   (0 – densely, shortly pubescent (hairs 0.2–0.3 mm long) or with numerous distinctive prickle-hairs; 1 – glabrous or with scattered long (around 0.5 mm) hairs). Use of a stereomicroscope, magnification 40x.
3. MRG.pub – the type of the marginal leaf-blade pubescence of the tillers
   (0 – glabrous; 1 – margin with scattered, long (around 0.5 mm) hairs). Use of a stereomicroscope, magnification 40x.
4. LF.flt – the flatness of leaf-blade of tillers
   (0 – the blade flat or U-shaped; 1 – the blade not flat, involute or tightly folded).
5. AX.pub – the type of pubescence of the panicle axes
   (0 – glabrous or prickly pubescent; 1 – pubescent). Use of a stereomicroscope, magnification 40x.

6. BR.pub – the type of pubescence of the panicle branches
   (0 – glabrous or prickly pubescent; 1 – pubescent). Use of a stereomicroscope, magnification 40x.
7. LMA.pub – the pubescence of the lemma
   (0 – glabrous; 1 – pubescent). Use of a stereomicroscope, magnification 40x.

Attributive characters:

8. SHT.pub – the type of pubescence of the tiller leaf-sheaths
   (0 – glabrous or at most sparsely prickly pubescent in the upper part of the sheath; 1 – leaf-sheaths with scattered, erect, long (around 0.5–1.5 mm) hairs, sometimes also numerous short hairs or prickles present; 2 – densely, shortly pubescent (hairs 0.2–0.4 mm long). Use of a stereomicroscope, magnification 40x.
9. CLM.pub – the type of pubescence of the culm
   (0 – glabrous or prickly pubescent; 1 – scattered, erect, long (around 0.5–1 mm) hairs at least around the node; 2 – densely, shortly pubescent (hairs 0.2–0.4 mm long) at least in the lower half of culm). Use of stereomicroscope, magnification 40x.
10. LOLF.pub – the type of pubescence of the lower leaf-blade surface of the culm leaves
    (0 – glabrous or prickly pubescent; 1 – scattered, long (around 0.5–1.5 mm) hairs; 2 – densely, shortly pubescent). Use of stereomicroscope, magnification 40x.

Quantitative characters:

11. TLR.l – the tiller length (cm)
12. TLRLF.w – the tiller leaf width (measured on well developed, flattened leaf from the middle of the tiller, about 2 cm above the ligule; cm)
13. CLM.l – the culm length (cm)
14. CLMLF.l – the culm leaf-blade length (measured on the second leaf from the top of the culm; cm)
15. CLMLF.w – the culm leaf-blade width (measured on the second leaf from the top of the culm, about 2 cm above the ligule, mm)
16. PNC.l – the panicle length (distance from the lowest node of panicle to the top, including the upper spikelet; cm)
17. SHOBR.l – the length of the shortest branch on the lowest node of panicle (mm)
18. LOBR.l – the length of the longest branch on the lowest node of panicle (mm)
19. IND1.l – the length of the first internode of the panicle axis (the distance between the lowest – the first and the nearest upper – second node of panicle; mm)
20. IND2.l – the length of the second internode of the panicle axis (the distance between the second and the third node of panicle; mm)
21. IND3.l – the length of the third internode of panicle axis (the distance between the third and the forth node of panicle; mm)
22. SPK.l – the spikelet length (measured on a well developed, complete spikelet from the middle of the panicle, the awns not included; mm)
23. RHIND.l – the rhachilla internode length (the distance between the first and the second floret; mm)
24. GLM1.l – the lower glume length (mm)
25. GLM2.l – the upper glume length (mm)
26. LMA.l – the lemma length (awn not included; mm)

27. AW.l – the awn length (measured from the lemma top; mm)
28. PLA.l – the palea length (mm)
29. BRMSPK.n – the number of the primary panicle branches with two or more spikelets
30. SHOBR.n – the number of the primary panicle branches, shorter or as long as their spikelets
31. BR.n – the number of the primary panicle branches
32. SPK.n – the number of the spikelets
33. ND.n – the number of the panicle nodes
34. BRND.n – the number of the panicle branches on the lowest panicle node
35. LMA.n – the number of the lemmas in the spikelet

In addition, some combinations, i.e. ratios of various basic quantitative characters were also taken into account, presuming to reflect the among-group differences better that the individual characters. These indices were:

36. TLR.l/CLM.l – ratio of the length of the tiller to the length of the culm (char. 36 = char. 11/char. 13)
37. PNC.l/CLM.l – ratio of the length of the panicle to the length of the culm (char. 47 = char. 16/char. 13)
38. SPK.n/PNC.l – ratio of the number of spikelets to the length of panicle, as a measure for the panicle density (char. 38 = char. 32/char. 16)
39. SPK.l/SHOBR.l – ratio of the length of a spikelet to the length of the shortest primary branch in the lowest node of panicle (char. 39 = char. 22/char. 17)
40. SHOBR.n/BR.n – ratio of the number of primary panicle branches, shorter or as long as their spikelets, to the number of all primary panicle branches, as a measure for the panicle density (char. 40 = char. 30/char. 31)
41. SHOBR.l/LOBR.l – ratio of the length of the shortest to the the length of the longest primary branch on the lowest panicle node (char. 41 = char. 17/char. 18)
42. BRMSPK.n/BR.n – ratio of the number of the primary panicle branches with 2 or more spikelets, to the number of all primary panicle branches (char. 42 = char. 29/ char. 31)
43. IND1.l/IND2.l – ratio of the length of the first to the length of the second panicle axis internode (char. 43 = char. 19/char. 20)
44. GLM1.l/GLM2.l – ratio of the length of the first to the length of the second glume (char. 44 = char. 24/char. 25)
45. LMA.l/GLM2.l – ratio of the length of the lemma to the length of the upper glume (char. 45 = char. 26/char. 25)
46. AW.l/LMA.l – ratio of the length of the awn to the length of the lemma (char. 46 = char. 27/char. 26)
47. LMA.n/SPK.l – ratio of the number of lemmas to the length of the spikelet, as a measure for the spikelet density (char. 47 = char. 35/char. 22)
48. RHIND.l/LMA.l – ratio of the rhachilla internode length to the length of the lemma, as a measure for overlapping of florets (char. 48 = char. 23/char. 26)

2.3. Morphometric Analysis

To form a hypothesis about the taxonomic structure of the group, i.e. to obtain clusters, cluster analysis (average linkage – UPGMA, minimization of error sum of squares – MNSSQ, minimization of variance in new cluster – MNVAR and minimization of increase of variance – MIVAR, based on Gower and/or distance coefficient) and principal coordinates analysis (PCoA, based on distance and Gower coefficient) were performed; in these analyses only binary and attributive characters were used. The different clustering strategies were used to achieve stable clusters and to separate outliers – OTUs, changing their cluster alliance (in the cluster analysis) and OTUs with intermediate position between clusters (in PCoA). These OTUs were temporarily excluded from further analysis and individually investigated later in the study.

The hypothesis, based on the results of previous methods, was then tested by discriminant analysis (canonical variates analysis CVA), using an independent set of characters – quantitative characters. To avoid overweighing of certain characters, the ratios were excluded from the discriminant analysis. On the basis of CVA some additional outliers were detected. CVA also provided information about the contribution of each character to the cluster discrimination.

To study the discriminative power of the quantitative characters, some univariate statistics were used. Within every cluster, the mean, minimum, maximum and the 1^{th} and the 9^{th} decile values were computed for each character. To evaluate the importance of the attributive and binary characters, the relative frequencies of the character states were calculated for each cluster.

Having evaluated the discriminative characters, the outliers were investigated individually and identified when possible. The information from the previous cluster analysis and PCoA was used, and in addition CVA scores were calculated for each outlier to obtain its position in CVA scattergram.

Cluster analyses, principal coordinate analysis and canonical variates analysis were performed using SYN-TAX 5.0 software package (Podani 1993, 1994).

As an alternative way to achieve an insight into the applicability of the characters for the splitting of objects in the clusters, and as an additional aid in constructing the classification key, a tree-based partitioning method – 'classification-tree' was applied. We used S-Plus package (Venables & Ripley 1994). During the procedure, variables are selected to split a-priori classified objects in order to correctly classify them. The method allows us to include all the various types of characters and it doesn't assume that quantitative characters are normally distributed.

3. Results

3.1. Morphometric Analysis

The results of the cluster analysis and the principal coordinates analysis based on attributive and binary characters indicate that three basic groups of OTUs can be recognized. In general the structure of the groups corresponds to the preliminary provisional determination of plants: the three clusters coincide with the three taxa: *Bromus erectus*, *B. transylvanicus* and *B. condensatus* (Fig. 1, 2). In this step 28 OTUs (14%) were temporarily excluded as outliers.

According to the results of discriminant analysis (Fig. 3) the three clusters can at least in part be separated by the quantitative characters. Along the first discrimination axis the '*B. erectus*' cluster is well separated

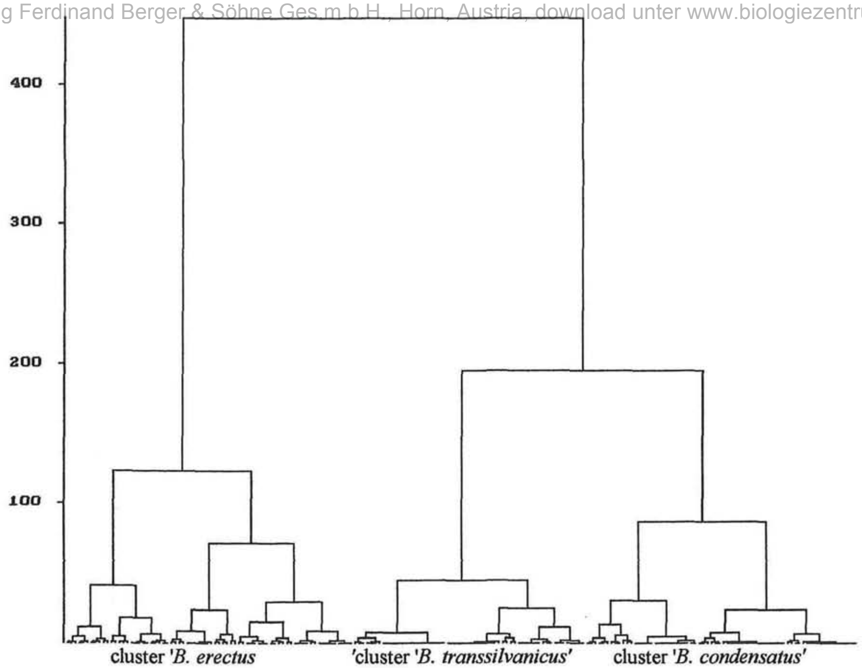

Fig. 1. Cluster analysis (MNSSQ, based on distance) of 198 herbarium specimens of *Bromus erectus* group in Slovenia.

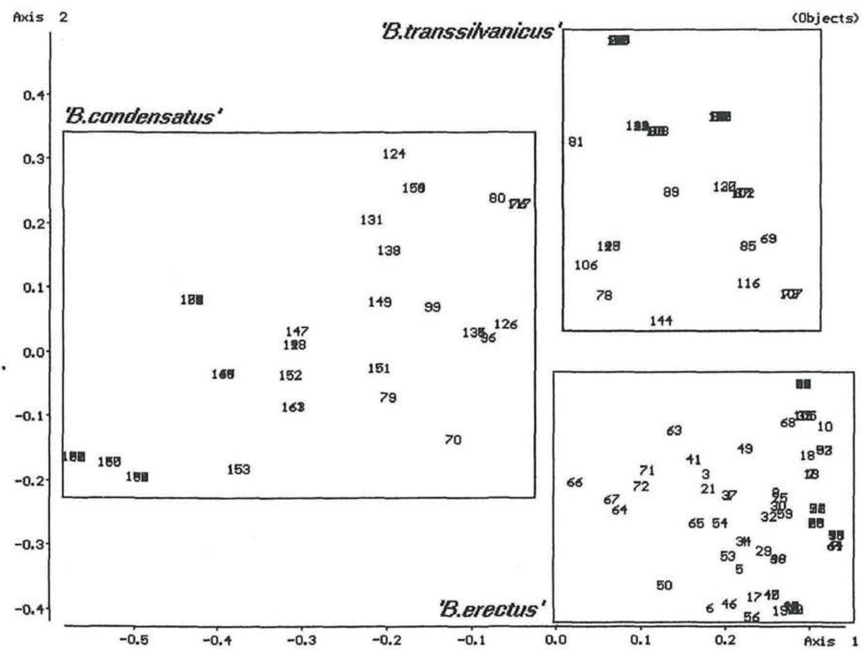

Fig. 2. Principal coordinates analysis (PCoA, based on Gower index) of 198 herbarium specimens of *Bromus erectus* group in Slovenia (The horizontal axis divides the '*B. condensatus*' cluster from the '*B. transylvanicus*' and '*B. erectus*' clusters and the vertical axis divides the cluster '*B. transylvanicus*' fom '*B. erectus*'. Clusters are outlined and labeled manually.)

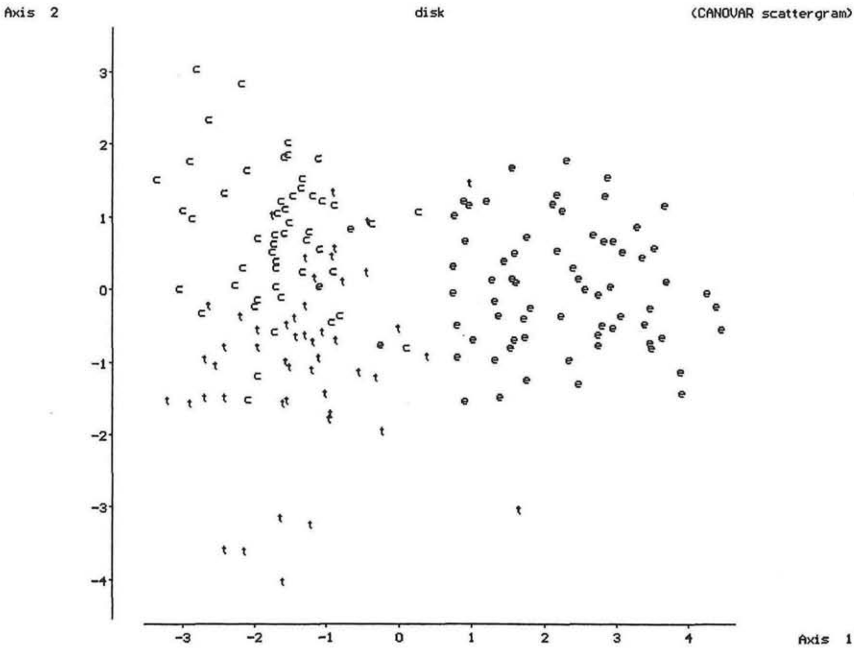

Fig. 3. Canonical discriminant analysis of the *Bromus erectus* group in Slovenia. c – '*B. condensatus*' cluster, t – '*B. transylvanicus*' cluster, e – '*B. erectus*' cluster.

from the other two groups. The second axis separates the '*B. condensatus*' cluster from the '*B. transylvanicus*' cluster with considerable overlap, indicating that the two taxa can not be successively separated solely by the quantitative characters. 4 OTUs with intermediate position between '*B. erectus*' cluster and the other two were excluded as outliers.

In the two phases of morphometric analysis about 16% of all OTUs were recognized as outliers.

3.2. The Discriminative Characters

In general the attributive and binary characters (Table 1) proved to be very useful in cluster separation, though some of them appear to be over-emphasized in various keys. For instance, in the case of SHT.prs (char. 1), LF.flt (char. 4) and LMA.pub (char. 7) the presence of a certain character state only reduces the number of possible determinations, since the distribution of the states does not match the taxonomic structure of the total sample perfectly. Characters SHT.pub (char. 8), UPLF.pub (char. 2) and MRG.pub (char. 3) are the most valuable characters for delimitation of the three taxa.

Of the 38 quantitative characters in the study, only 14 characters proved to be useful in discriminating the clusters, at least in part (Table 2). Some of the characters, presented in keys and Floras as important

Table 1.
Frequencies of states of the binary and attributive characters in the three clusters of *Bromus erectus* group.

		Frequency in the group (%)		
Character	State	*B. erectus*	*B. transylvanicus*	*B. condensatus*
SHT.prs (1)	0	42	75	100
	1	58	25	0
UPLF.pub (2)	0	10	100	100
	1	90	0	0
MRG.pub (3)	0	0	54	100
	1	100	46	0
LF.flt (4)	0	52	77	98
	1	48	23	2
AX.pub (5)	0	82	100	63
	1	18	0	37
BR.pub (6)	0	64	100	69
	1	36	0	31
LMA.pub (7)	0	57	100	100
	1	43	0	0
SHT.pub (8)	0	0	100	0
	1	100	0	0
	2	0	0	100
CLM.pub (9)	0	39	100	37
	1	55	0	0
	2	6	0	63
LOLF.pub (10)	0	66	100	10
	1	34	0	2
	2	0	0	88

(Smith 1980: 185, Pignatti 1987: 522–523, Ascherson & Graebner 1898–1902: 577–589, Hess & al. 1967: 162–163, Degen 1936: 558), proved to be ambiguous or to have no discriminative power for separating the clusters, namely GLM1.l/GLM2.l (char. 44), LMA.l/GLM2.l (char. 45) and RHIND.l/LMA.l (char. 48) for discrimination between *B. transylvanicus* and *B. erectus*. The attempts to evaluate the panicle characters (char. 16–21, 38–43) resulted in 5 useful or at least partly useful characters and two of them proved to be of great importance for *B. transylvanicus* – *B. erectus* separation: SPK.l/SHOBR.l (char. 39) and SHOBR.n/BR.n (char. 40). These two characters are often used in various keys and Floras (Smith 1980: 185,

Table 2.
Discriminative quantitative characters; measures are stated as (minimum-) 1.decile – 9.decile (-maximum) value

Quantitative character	*B. erectus*	*B. transylvanicus*	*B. condensatus*
TLRLF.w (12)	(1-) 1.5–2.5 (-4) mm	(0.5-) 1–2 (-3) mm	(0.5-) 0.5–1.5 (-2) mm
CLM.l (13)	(40-) 60–100 (-110) cm	(40-) 40–70 (-100) cm	(30-) 40–70 (-80) cm
CLMLF.w (15)	(1.5-) 2–4 (-5) mm	(1-) 1.5–2.5 (-5) mm	(0.5-) 0.5–2 (-3) mm
PNC.l (16)	(8-) 10–16 (-20) cm	(5-) 8–14 (-16) cm	(5-) 6–12 (-14) cm
SHOBR.l (17)	(1-) 3–15 (-36) mm	(3-) 10–31 (-52) mm	(4-) 9–23 (-28) mm
INDl.l (19)	(15-) 19–38 (-50) mm	(11-) 15–32 (-38) mm	(7-) 10–27 (-32) mm
SPK.l (22)	(12-) 20–27 (-50) mm	(12-) 15–25 (-30) mm	(11-) 15–22 (-25) mm
LMA.l (26)	(9-) 10–13 (-15) mm	(8-) 9–12 (-14) mm	(8-) 9–11 (-11) mm
AW.l (27)	(3-) 4–7 (-8) mm	(3-) 3–6 (-7) mm	(1-) 2–4,5 (-5,5) mm
SHOBR.n (30)	(2-) 6–18 (-25)	(1-) 2–8 (-12)	(2-) 3–8 (-10)
BRND.n (34)	(2-) 3–6 (-9)	(2-) 2–4 (-6)	(2-) 2–5 (-7)
SPK.l/SHOBR.l (39)	(0.7-) 1.7–7.7 (-25)	(0.4-) 0.6–1.8 (-7.3)	(0.6-) 0.7–1.9 (-4)
SHOBR.n/BR.n (40)	(0.2-) 0.6–0.9 (-1)	(0.1-) 0.2–0.6 (-0.8)	(0.3-) 0.4–0.8 (-1)
SHOBR.l/LOBR.l (41)	(0.2-) 0.3–0.7 (-0.8)	(0.4-) 0.5–0.8 (-0.9)	(0.1-) 0.4–0.8 (-0.9)

CONERT 1996–97: 710–757, ASCHERSON & GRAEBNER 1902: 577–589). On the other hand, contrary to some reports (HESS & al. 1967: 362–363, CONERT 1996–97: 710–757, ASCHERSON & GRAEBNER 1898–1902: 577–589), BRMSPK.n/BR.n (char. 42) proved to have no discriminative power.

While most of the measures can successfully discriminate between *B. condensatus* and *B. erectus* and at least satisfactorily divide *B. erectus* cluster from the rest, no quantitative character can unambiguously separate *B. transylvanicus* and *B. condensatus*. This fact supports the findings of CONERT 1996: 735, that *B. transylvanicus* and *B. condensatus* are in much closer relationship than they are with *B. erectus*.

3.3. Altitude Differentiation and Flowering Time

Data given on the herbarium labels were used to gather information about altitude preferences and flowering time of the taxa. *B. transylvanicus* and *B. condensatus* are ecogeographical vicariants: *B. transylvanicus* grows above (600-) 800 m a.s.l. in the mountain and subalpine belt, while *B. condensatus* is a lowland species, growing below 600 m. *B. erectus* is distributed from lowlands to the subalpine belt (Figs. 5, 6) The taxa differ in flowering time as well. *B. condensatus* flowers from April to June, *B. erectus* and *B. transylvanicus* from May to August. According to POLDINI 1966: 214–216 the flowering time differentiation of *B. condensatus* and *B. erectus* can also be observed wherever the two grow together: when the first one is ripening, the other is still in anthesis.

3.4. The 'Outliers'

As has already been stated, there were 31 OTUs (16% of the whole sample) recognized as outliers at various stages of our analysis. Considering them individually, 2/3 of the outliers could have been explained by larger intraspecific variability: unusually pubescent forms of *B. transylvanicus* or unusually glabrous forms of *B. condensatus*, which shifted between '*B. transylvanicus*' and '*B. condensatus*' clusters due to some unusual combination of untypical states. The 'pubescent forms' of *B. transylvanicus* differed from the typical majority mainly in pubescence of the culm, panicle axes and branches; in only two OTUs densely shortly pubescent sheaths were present. All of these OTUs were collected in higher altitudes. In case of the 'glabrous forms' of *B. condensatus*, the combination of glabrous culm and glabrous abaxial leaf-blade surface is present. Both of the states are rare in typical *B. condensatus* and common in *B. transylvanicus*.

According to the intermediate states of the studied characters, 9 outliers are presumed to be hybrids: after the analysis, six plants were determined as *B. erectus x transylvanicus*, two as *B. erectus x condensatus* and one as *B. transylvanicus x condensatus*.

3.5. The Classification-tree

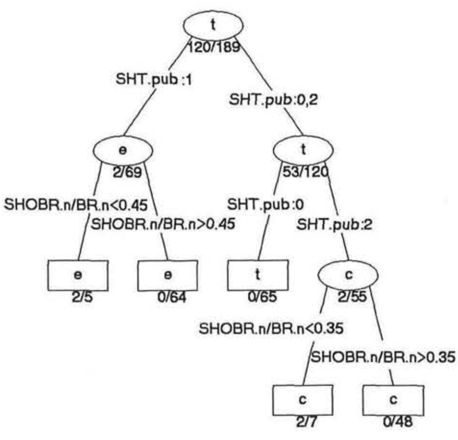

Fig. 4. Classification-tree. The labels in the nodes represents the determinations: c – *B. condensatus*, t – *B. transylvanicus*, e – *B. erectus*. The ratio underneath the nodes denote the misclassification proportion.

The input matrix for the construction of the classification-tree contained all the 48 characters in the study and all the identified OTUs, including those outliers, which were not presumed to be hybrids. The tree obtained (Fig. 4) managed to classify correctly 92% of objects according to the pubescence-type of basal leaf-sheaths (SHT.pub), but only 4 OTUs, pre-determined as 'unusually pubescent forms' of *B. transylvanicus*, were misclassified. Two of them were classified as '*B. erectus*' and the other two as '*B. condensatus*'. The ratio of the number of primary panicle branches, shorter than their spikelets, to the number of all primary panicle branches (SHOBR.n/BR.n) was used to separate misclassified OTUs from the rest, but less successfully.

3.6 Diagnostic Key

The three taxa in the study can be identified according to the following classification key:

1 Upper leave-blade surface glabrous or with scattered long (around 0.5 mm) hairs. Basal leaf-sheaths with scattered, erect, long (around 0.5–1.5 mm) hairs. (2-) 6–18 (-25) panicle branches shorter then their spikelets. Spikelets 2–8 x (-25x) longer then the shortest branch on the lowest node of the panicle. Lemmas glabrous or pubescent. – Leaf-blade margins with long scattered hairs; leaf-blade of tillers flat, involute or folded; leaf-sheaths of tillers eventually decaying into parallel fibers or persistent when dead. Widespread plant.

B. erectus

1* Upper leave-blade surface densely, shortly pubescent (hairs 0.2–0.3 mm long) or with numerous distinctive prickle-hairs. Basal leaf-sheaths glabrous or densely, shortly pubescent (hairs 0.2–0.4 mm long). (1-) 2–8 (-12) panicle branches shorter then their spikelets. Spikelets at most 2 × longer than the shortest branch on the lowest node of the panicle, but usually the branch longer than its spikelet. Lemmas glabrous, never pubescent.

2 Basal leaf-sheaths glabrous or at most sparsely prickly pubescent in the upper part of the sheath; leaf-blade margins glabrous or with long scattered hairs; leaf-blade of tillers flat, involute or folded; leaf-sheaths of tillers eventually decaying into parallel fibers or persistent when dead. Plant of greater altitudes (above 800 m a.s.l.).

B. transylvanicus

2* Basal leaf-sheaths densely, shortly pubescent (hairs 0.2–0.4 mm long); leaf-blade margins glabrous, never pubescent, leaf-blades of tillers always involute or folded, never flat; leaf-sheaths of tillers relatively quickly decaying into parallel fibers, never persistent. Lowland plants (below 600 m a.s.l.).

B. condensatus

3.7. Note on the Distribution of the Taxa in Slovenia

B. transylvanicus and *B. condensatus* are very similar, closely related taxa and also ecogeographical vicariants – their niches are at different altitudes: *B. transylvanicus* grows in the mountains, in Slovenia mostly in the Alpine and Prealpine phytogeographical region, while in some other regions of Slovenia it is only scattered – wherever higher altitudes are present; *B. condensatus* can be found in South-Eastern (mostly in the Coastal region) and also in the Central part of Slovenia (Fig. 5), on warm, limestone slopes with southern exposure. *B. erectus* occurs all over the territory (Fig. 6).

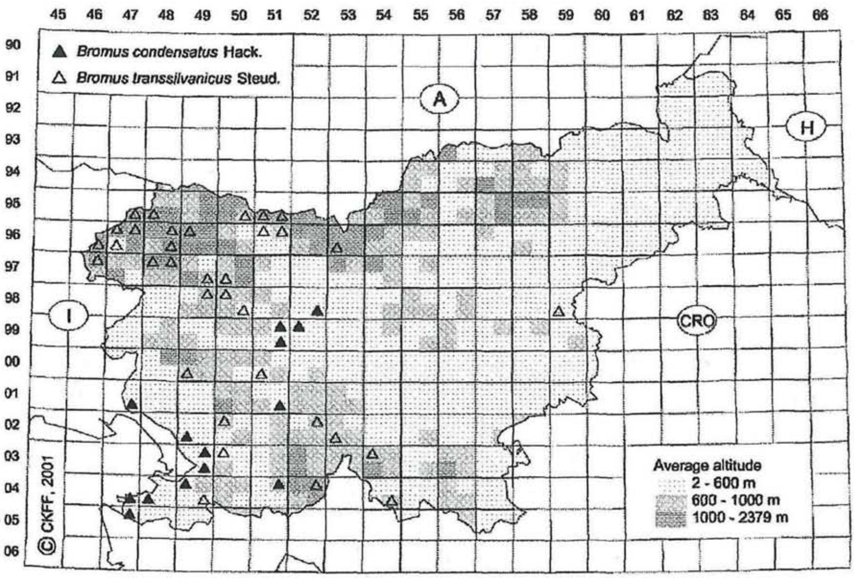

Fig. 5. The known distribution of *Bromus transylvanicus* and *B. condensatus* in Slovenia.

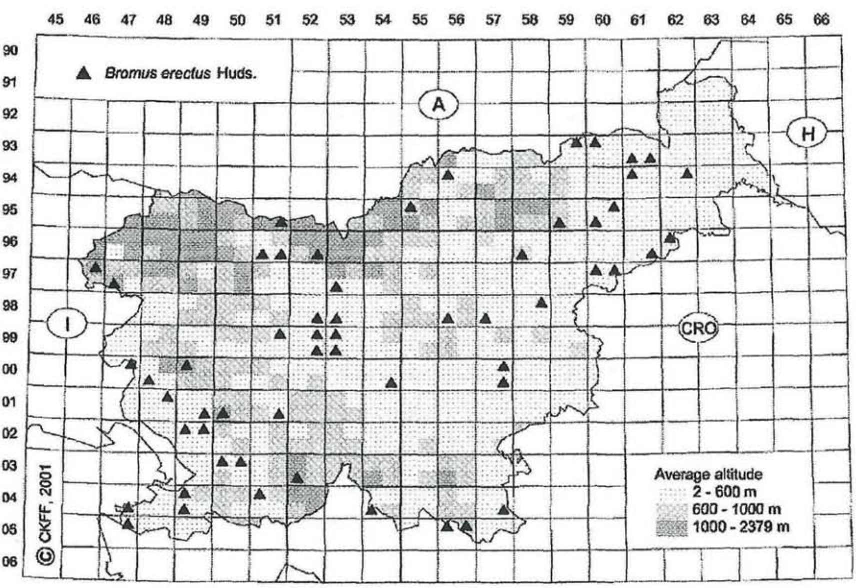

Fig. 6. The known distribution of *Bromus erectus* in Slovenia.

4. Discussion and Conclusions

The results of the study confirm the occurrence of *B. erectus* (s.str.), *B. transylvanicus* and *B. condensatus* in Slovenia. On infraspecific rank all the plants determined as *B. condensatus* belong to var. *microtrichus* BORB., due to their very shortly (0.2–0.4 mm) pubescent leaf-sheaths. The typical *B. condensatus* var. *condensatus*, occuring in the regions north-west (e.g. Southern Switzerland, North-Eastern Italy) and south (e.g. Istria) from the studied territory, has much longer hairs (about 1 mm). Whether the two varieties merit the subspecific rank (cf. JOGAN 2001: 26) can still be a matter of discussion.

Due to the close relationship of *B. transylvanicus* and *B. condensatus*, delimitation of the two remains problematic. They can be quite reliably be distinguished by the combination of attributive characters, i.e. the pubescence-types of basal leaf-sheaths and leaf-blade margins, persistency of leaf-sheaths and flatness of blades, but some forms appear to be in somehow intermediate position. Besides additional macromorphological characters other sets of characters, such as micromorphological, anatomical and karyological data should be investigated in the future.

The occurrence of *B. pannonicus* and *B. moellendorfianus* remains unconfirmed. The common feature of the two taxa is the presence of long rhizomes. Among the plants in the study no specimen matched the descriptions of either of them. According to ASCHERSON & GRAEBNER 1901: 582 *B. moellendorfianus* is a very unique taxon and easy to identify since the spikelets appear silvery glossy due to typically wide hyaline margins of the lemma. The recent record of this Central-Balkan species for the Julian Alps (PETROVA & al. 1993: 186) seems quite unlikely.

In respect to the reports of *B. pannonicus* for Slovenia (CONERT 1997: 737) there is no certain locality or voucher specimen available. However, according to some older reports for the northern Croatia (POSPICHAL 1897: 127) and especially according to the recent reports for Austria (MELZER 1980: 48, 1981: 119, 1984: 25–26) and Italy in the vicinity of Trieste (PIGNATTI 1983: 523), *B. pannonicus* is likely to be found in Slovenia, too. POLDINI 1991: 804 comments, that the occurence of *B. pannonicus* (as well as *B. transylvanicus*) in Friuli–Venezia Giulia has not been confirmed recently.

The reports of *B. stenophyllus* for Slovenia are based on the findings of FLEISCHMANN 1844: 14 and PAULIN 1936 (in schedis, sec. WRABER 1966: 140). The revision of the voucher specimens, preserved in the herbarium collections 'Flora exsiccata carniolica' (herbarium LJU) and 'Flora germanica exsiccata' (herbarium LJM), showed that the material was misidentified: correct determination is *B. transylvanicus*.

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