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The differing characteristics of *Brachypodium pinnatum* (L.) P. Beauv. and *B. sylvaticum* (Huds.) P. Beauv.

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Abstract. *Brachypodium pinnatum* and *B. sylvaticum* are two well known, closely related and similar species within the genus *Brachypodium*. A number of differing characteristics between these two species is examined. *B. pinnatum* and *B. sylvaticum* cannot be distinguished on the basis of qualitative characteristics suggested by different taxonomists, such as the shape of the ligule, hairiness of leaves and sheaths, and presence or absence of hairs on the leaf margins.

Key words: *Brachypodium pinnatum*, *B. sylvaticum*, differences, Poaceae, Poland

1. Introduction

The genus *Brachypodium* is represented in the Polish flora by two native species: *B. pinnatum* (L.) P. Beauv. and *B. sylvaticum* (Huds.) P. Beauv. Third *B. distachyon* (L.) P. Beauv. is listed as an ephemerophyte (Mirek *et al.* 2002). The Eurosiberian *Brachypodium pinnatum* is a common species in Poland, known from numerous localities situated in lowland areas, and particularly in submontane belt (Hultén & Fries 1986; Mirek & Piękoś-Mirkowa 2003). Its ecological centre is located in the Małopolska and Lubelska Uplands, and in the zone between the lower Vistula and lower Oder rivers. It is uncommon to rare in the central and north-eastern part of Poland (Zając & Zając 2001). *B. pinnatum*, a mesophilous grass, in Poland occupies diverse habitats. *B. pinnatum* is predominantly a characteristic species of seminatural species-rich chalk xerothermic grasslands of the *Festuco-Brometea* class and occurs in Poland with a high frequency in the following communities: *Origano-Brachypodietum* and *Adonido-Brachypodietum* (Matuszkiewicz 2002). It is also a differential species of thermophile fringe vegetation of *Trifolion medii* and a frequent member of chalk scrub and wood margins. Furthermore, this species sometimes occurs in ruderal habitats (Korniak 2003). Numerous specimens of *B. pinnatum* in the major Polish herbaria were collected in open woodlands, for instance, in thermophilous oak forest (*Potentillo albae-Quercetum*) or mixed forests (*Pino-Quercetum, Melitti-Carpinetum*).

B. sylvaticum is native to North Africa, Europe and Asia. *B. sylvaticum* is noted in the whole of Poland, but predominantly in lowland and submontane habitats, being most widespread in south-eastern Poland (Zając & Zając 2001). *B. sylvaticum* is most commonly found in woods, copses, along hedgerows, and in other shady places, but may also grow in a grassland and along roadsides – in areas that were originally woodland. It is a characteristic species of the *Querco-Fagetea* class and a differential species of the *Alliarion* alliance (Matuszkiewicz 2002).

B. pinnatum and *B. sylvaticum* have small chromosomes with a variable base number (x = 7 or 9), making them unusual in the Pooideae, which tend to have large chromosomes and a base number of 7 (Shi *et al.* 1993). *B. pinnatum* is usually a tetraploid based on x = 7 (2n = 28), although some variations, e.g., 2n = 14, 16, 18, 20 and 36 have been found. *B. sylvaticum* is usually a diploid based on x = 9 (2n = 18), but counts of 2n = 14, 28, 42 and 56 have been reported. The most common counts were confirmed also for the Polish populations of *B. pinnatum* and *B. sylvaticum* (Pogan *et al.* 1980, 1983; Schippmann 1991).

B. pinnatum is largely self-incompatible, i.e. an individual cannot fertilise its own seed, so requiring a pollen transfer from another individual, whereas *B. sylvaticum* is highly self-compatible (Khan & Stace 1999). Despite the low proportion of sexual recruitment, clonal diversity within the population of *B. pinnatum* was higher than reported for other clonal plant populations (Schläpfer & Fischer 1998).

B. pinnatum and *B. sylvaticum* overlap with one another in most of their morphological characters (Smith 1980). As such, Saint-Yves (1934) had earlier recognised only one species – *B. pinnatum* (L.) P. Beauv. including *B. sylvaticum* (Huds.) P. Beauv. as a variety, var. *silvaticum* St-Y. According to Hubbard (1968), *B. pinnatum* is distinguished from *B. sylvaticum* by its form of growth, the presence of rhizomes, usually hairless culms and leaf-sheath, stiffer racemes and especially by the shorter-awned lemmas. On the contrary, Johnson (2004) considered the most distinctive feature for identification of *B. sylvaticum* in the USA, a single row of ciliate-pilose hairs fringing the leaf blade, similar hairs covering the leaf-sheath and accentuated at the collar. However, according to Rothmaler (1995), not *B. sylvaticum* but *B. pinnatum* is characterised by a single row of ciliate-pilose hairs fringing the leaf blade. On the other hand, Catalán and Olmstead (2000) acknowledge that both species have recently diverged within the genus *Brachypodium* and exhibit hairy blades and spikelets, while Khan (1984) emphasizes that *B. sylvaticum* accumulates a number of autopomorphies, like nodding panicles, as well as long awned lemmas, less vigorous rhizomes, and a high percentage of self-fertility.

The present study was designed to examine the morphology, especially the qualitative characteristics, in an attempt to determine whether *B. pinnatum* and *B. sylvaticum* are consistently and reliably distinguishable.

2. Material and methods

The 13 accessions of *B. pinnatum* (320 individuals) and 12 of *B. sylvaticum* (275 individuals) collected from different habitats are described in Table 1 and mapped in Figure 1. Due to the rhizomatous habit of *B. pinnatum*, plants were collected a few metres apart to avoid sampling from the same vegetative clone. Each accession consists of between 11 and 25 plants (usually 25) (Table 1). The material was deposited in the herbarium of the Institute of Botany in Kraków (KRAM).

Based on previous morphological studies in *Brachypodium* (Schippmann 1991; Rothmaler 1995; Johnson 2004), four quantitative (Table 2) and eight qualitative traits were selected (Table 3-4). Characters were assessed or measured with a ruler or a Nikon stereoscopic zoom microscope. The assessment of palea glabrousness or pubescence is without regard to stiff-cilia on the keels and at the apex. A palea that is glabrous except for the cilia on the keel and at the apex is called glabrous. Descriptive statistics of quantitative characters were calculated for each taxon, based on the entire data set. Box-and-whisker plots and a histogram were used to display this data.

3. Results and discussion

The most remarkable difference between *B. pinnatum* and *B. sylvaticum* is the lemma awn length, measured at the first floret in the fourth spikelet as well as at the fourth floret in the fourth spikelet, giving the derived variable ratio: lemma awn length/lemma length (Table 2, Fig. 2). The frequency distribution for the number of lower glume nerves in both species has relatively little overlap (Fig. 2). The most frequent number of lower glume nerves of *B. pinnatum* is from 3 to 5 (most frequently 3), and occasionally 6. The

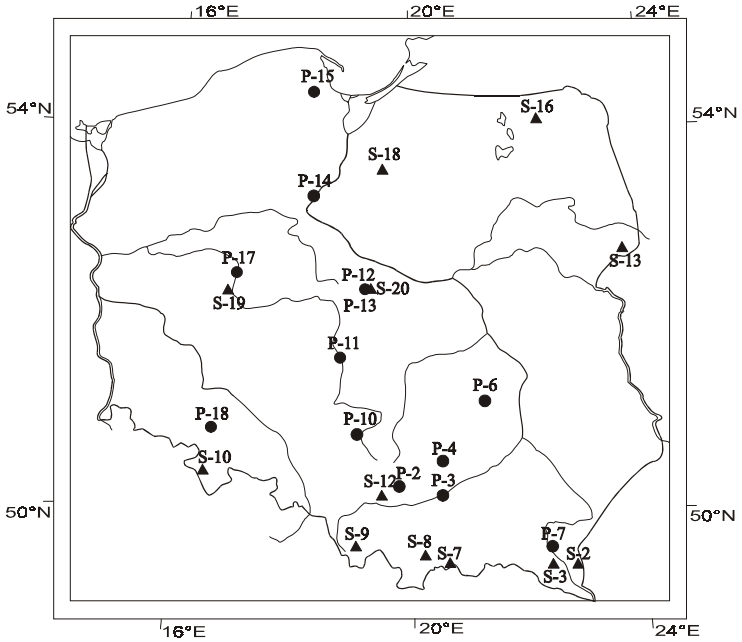

Fig. 1. Map of Poland with geographic locations of the sampled populations of *Brachypodium pinnatum* (black dots) and *B. sylvaticum* (black triangles)

Table 1. Accessions of *Brachypodium pinnatum* (P) and *B. sylvaticum* (S) collected by B. Paszko. The number of plants measured in each accession is given in brackets

B. pinnatum
P-2: (25) Kraków vicinity, Ojcowski National Park, Pieskowa Skała, steep escarpment, N 50°13', E 19°49'; **P-3:** (25) Kraków vicinity, Hebdów, steep escarpment alongside the Vistula River, N 50°08', E 20°24'; **P-4:** (25) Kielce vicinity, Góry Pińczowskie reserve, calcareous xerothermic grassland, N 50°32', E 20°30'; **P-6:** (25) Iłża, xerothermic grassland, N 51°10', E 21°15'; **P-7:** (25) Sanok vicinity, Trepcza, a steep escarpment alongside the San River, N 49°36', E 22°12'; **P-10:** (25) Częstochowa vicinity, Olsztyn, castle hill, calcareous semi-natural dry grassland, N 50°45', E 19°16'; **P-11:** (25) Sieradz vicinity, Półboru reserve, thermophilous oak forest (*Potentillo albae-Quercetum*), N 51°36', E 18°49'; **P-12:** (25)**, P-13:** (20) Łódź vicinity, Krośniewice, Świetlista Dąbrowa reserve, thermophilous oak forest, N 52°17', E 19°12'; **P-14:** (25) Bydgoszcz vicinity, Plutowo, Zbocza Plutowskie reserve in the valley of the Lower Vistula River, xerothermic grassland (*Adonido-Brachypodietum*), N 53°16', E 18°23'; **P-15:** (25) Gdańsk vicinity, Małkowo, roadside, N 54°22', E 18°21'; **P-17:** (25) Poznań vicinity, Dziewicza Góra reserve, mixed forest edge, N 52°28', E 17°00'; **P-18:** (25) Wrocław vicinity, Ślęża Mt., the Tąpała pass, mixed forest edge, N 50°50', E 16°42'.
B. sylvaticum
S-2: (25) Sanok vicinity, Ustrzyki Dolne, quarry near roadside, N 49°19', E 22°38'; **S-3:** (25) Sanok vicinity, Baligród, roadside in forest, N 49°21', E 22°15'; **S-7:** (25) Nowy Targ vicinity, Little Pieniny Mts., Homole Gorge, N 49°24', E 20°33'; **S-8:** (25) Nowy Targ vicinity, Gorce Mts., Knurowska Pass, roadside, N 49°30', E 20°11'; **S-9:** (25) Beskid Śląski Range, Barania Góra Mountain, mixed forest near the Bystra River, N 49°37', E 19°02'; **S-10:** (25) Kłodzko vicinity, Polanica Zdrój, forest near the road to Szczytna, N 50°24', E 16°29'; **S-12:** (25) Katowice vicinity, NE Trzebinia: between Lgota and Myślachowice, roadside, N 50°11', E 19°31'; **S-13:** (25) Białystok vicinity, Bialowieża National Park, Hajnówka, forest near the roadside, N 52°43', E 23°37'; **S-16:** (25) Suwałki vicinity, Szwałk, forest between Szwałk Wielki Lake and the Szwałk Mały Lake, N 54°06', E 22°15'; **S-18:** (24) Grudziądz vicinity, Iława, forest near roadside, N 53°36', E 19°31'; **S-19:** (11) Poznań vicinity, Mosina, Wielkopolski National Park, mixed forest, N 52°16', E 16°49'; **S-20:** (15) Łódź vicinity, Krośniewice, Świetlista Dąbrowa reserve, thermophilous oak forest (*Potentillo albae-Quercetum*), N 52°17', E 19°12'.

lower glumes of *B. sylvaticum* have usually from 5 to 7 nerves (most frequently 6 or 7), and occasionally 4 (Fig. 2).

Almost all *B. sylvaticum* individuals have a short-ciliate abaxial surface of palea (272 of 275) and most of the *B. sylvaticum* plants have an obtuse ligule (231 of 275). These characters are not species-specific, because part of the *B. pinnatum* individuals (91 from 320 and 25 from 320 respectively), also have these attributes (Table 4). The penultimate leaves of most *B. pinnatum*

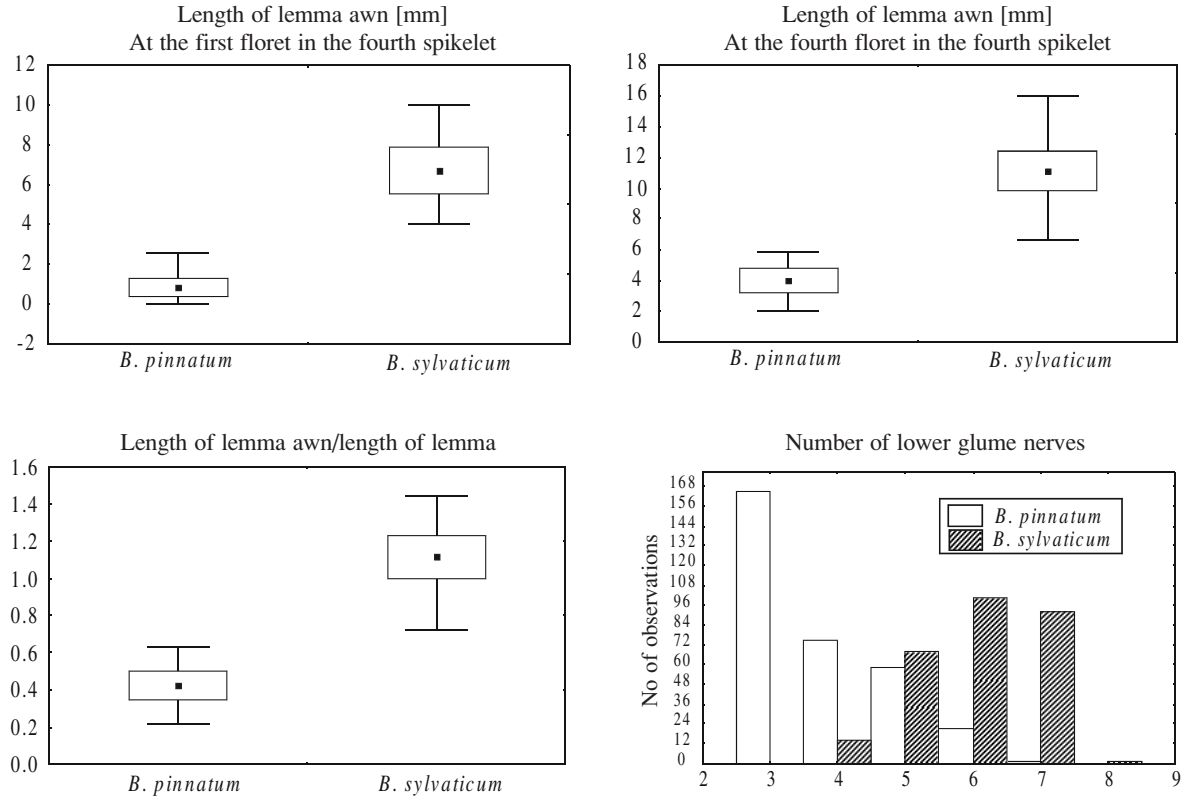

Fig. 2. Histogram and box plots with the mean (point), range of standard deviations (box) and minimum/maximum (whisker), indication of four differentiated characters for *B. pinnatum* (based on 320 specimens) and *B. sylvaticum* (based on 265 specimens)

Table 2. Differences between *Brachypodium pinnatum* and *B. sylvaticum*. For four quantitative characters the variability range is shown

Characteristic	*B. pinnatum*	*B. sylvaticum*
Pollination	self-incompatible (Khan & Stace 1999)	self-compatible (Khan & Stace 1999)
Chromosome number (the most common)	2n = 28 (Rychlewski in Pogan *et al.* 1983; Schippmann 1991)	2n = 18 (Rychlewski in Pogan *et al.* 1980; Schippmann 1991)
Syntaxonomical position (Class)	*Festuco-Brometea* (Matuszkiewicz 2002)	*Querco-Fagetea* (Matuszkiewicz 2002)
Habit	strongly rhizomatous (Falkowski 1982)	not rhizomatous (tufted) (Falkowski 1982)
Ratio: lemma awn length/lemma length	0.22-0.63	0.72-1.45
Length of lemma awn [mm] measured at the first floret in the fourth spikelet	0.0-2.6	4.0-10.0
Length of lemma awn [mm] measured at the fourth floret in the fourth spikelet	2.0-5.9	6.7-16.0
Number of lower glume nerves in the fourth spikelet	3-6(7)	(4)5-7(8)

individuals usually (85%) have hairy margins, whereas only 40% of *B. sylvaticum* plants have the same attribute (Table 4).

Johnson (2004) claimed that the most distinctive feature in identifying *B. sylvaticum* is the single row of ciliate-pilose hairs fringing the leaf blade, similar hairs covering the leaf-sheath and that accentuated at the collar. On the contrary, according to Rothmaler (1995), *B. pinnatum* plants have a leaf margin often conspicuously ciliate-pilose. A certain pattern of variation can be found as regards the hairiness of leaf margins, but this characteristic is not specific to any *Brachypodium* species studied (Table 4).

According to Hubbard (1968), *B. pinnatum* is distinguished from *B. sylvaticum* by its usually hairless culm and leaf-sheath. However, according to the author's observations, the pattern of variation within both the Polish *Brachypodium* species is very similar as regards the culm and leaf-sheath pubescence. When analysing leaf-sheaths, those on the lower half of the culm, totalling 90% and 63% of individuals of *B. pinnatum* and *B. sylvaticum* respectively, have hairy leaf-sheaths. Leaf-sheath pubescence, especially on the middle and lower part of the culm, is a dominant characteristic in both native species of *Brachypodium* in Poland. However, glabrousness is a dominant characteristic on the upper half of the culm, and 63% and 71% of individuals of *B. pinnatum* and *B. sylvaticum*, respectively, have glabrous uppermost leaf-sheaths (Table 2). Both studied species of *Brachypodium* consist of many forms as regards the hairiness of leaf-sheaths and leaves, from the almost glabrous types, through a multitude of intermediate forms, to abundant hairy types. Within both species, glabrous types are rather rare, and the most frequent are largely hairy individuals or plants of intermediate appearance in terms of their hairiness.

The recapitulation: Differences between *B. pinnatum* and *B. sylvaticum* based on morphology

The results revealed that *B. sylvaticum* differs from *B. pinnatum* by the following combination of characters: (1) the longer awn of the lemma of the fourth flower (6.7-16.0 mm vs. 2.0-5.9), (2) the perpetually short-ciliate hairy vs. usually glabrous palea abaxial surfaces, (3) the racemes, which tend to have less spikelets (5-10 vs. 6-16), (4) the lower glumes, which tend to have more nerves ((4)5-7(8)-nerved vs. 3-5(7)-nerved), (5) the penultimate leaves, which tend to be wider (5-10 mm vs. 2-8), and (6) longer lower glumes (5.5-10 mm vs. 3-8) (Fig. 2; Table 2). The most remarkable differences between *B. pinnatum* and *B. sylvaticum* are the length

Table 3. Qualitative characters descriptions and attributes and their frequencies in *Brachypodium pinnatum* and *B. sylvaticum*

Character	Character attributes	Frequency	
		B. pinnatum (N=320)	*B. sylvaticum* (N=275)
uppermost leaves: hairiness of sheaths	hairless/only margins hairy/hairy	43/158/119	22/171/82
middle leaves: hairiness of sheaths	hairless/only margins hairy/hairy	30/109/181	10/120/145
lowest leaves: hairiness of sheaths	hairless/only margins hairy/hairy	23/81/216	5/95/174
penultimate* leaf: hairiness on adaxial side	hairless/hairy	30/289	5/267
penultimate* leaf: hairiness on abaxial side	hairless/hairy	153/166	165/107

Explanation: *penultimate = second from the top

Table 4. The frequency distributions for three qualitative characters of 13 *Brachypodium pinnatum* (P) and 12 *B. sylvaticum* (S) accessions. N – number of individuals studied. For the accession abbreviations see Table 1

Accession abbreviation	N	Presence or absence of hairs on the margins of the penultimate leaf (next to the last leaf)		Ligule shape		Pubescence on abaxial surface of palea*	
		absent	present	truncate	obtuse	glabrous	short-ciliate
P-2	25	12	13	25	0	24	1
P-3	25	1	24	25	0	15	10
P-4	25	11	14	23	2	22	3
P-6	25	11	14	25	0	24	1
P-7	25	1	24	24	1	25	0
P-10	25	0	25	25	0	25	0
P-11	25	0	25	25	0	23	2
P-12	25	0	25	25	0	2	23
P-13	20	0	20	20	0	0	20
P-14	25	0	25	25	0	3	22
P-15	25	7	18	3	22	25	0
P-17	25	0	25	25	0	24	1
P-18	25	0	25	25	0	17	8
Total for *B. pinnatum*	320	43	277	295	25	229	91
S-2	25	0	25	3	22	0	25
S-3	25	14	11	0	25	0	25
S-7	25	7	18	0	25	0	25
S-8	25	1	24	1	24	0	25
S-9	25	25	0	1	24	0	25
S-10	25	25	0	2	23	0	25
S-12	25	0	25	8	17	0	25
S-13	25	25	0	22	3	0	25
S-16	25	25	0	0	25	0	25
S-18	24	24	0	3	21	0	24
S-19	11	11	0	0	11	0	11
S-20	15	0	15	4	11	3	12
Total for *B. sylvaticum*	275	157	118	44	231	3	272
Total	595	200	395	339	256	232	363

Explanation: *estimate at fourth floret in fourth spikelet

of the lemma awn, the presence of rhizomes, its type of habit, and stiffer racemes. Awn length is the best single character for identifying the two studied species.

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References

CATALÁN P. & OLMSTEAD R. G. 2000. Phylogenetic reconstruction of the genus *Brachypodium* P. Beauv. (Poaceae) from combined sequences of chloroplast *ndhF* gene and nuclear ITS. Plant Syst. Evol. 220:1-19.

FALKOWSKI M. (ed.) 1982. Trawy polskie. 565 pp. Państwowe Wydawnictwo Rolnicze i Leśne, Warszawa.

HUBBARD C. E. 1968. Grasses: a guide to their structure, identification, uses, and distributionin the British Isles. 463 pp. 2nd ed. Penguin Books. Harmondsworth, Middlesex, UK.

HULTÉN E. & FRIES M. 1986. Atlas of North European vascular plants. North of the Tropic of Cancer. I-III. xvi+1172 pp. Koeltz Scientific Books, Königstein.

JOHNSON J. 2004. *Brachypodium sylvaticum* (slender false-brome). Cal-IPC News 11: 10-11.

KHAN M. A. 1984. Biosystematic studies in *Brachypodium* (Poaceae). 353 pp. Dissertation, Leicester.

KHAN M. A. & STACE C. A. 1999. Breeding relationships in the genus *Brachypodium* (Poaceae: Pooideae). Nord. J. Bot. 19: 257-269.

KORNIAK T. 2003. Synanthropic grass species in Poland. In: L. FREY (ed.). Problems of grass biology, pp. 189-200. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

MATUSZKIEWICZ W. 2001. Przewodnik do oznaczania zbiorowisk roślinnych Polski. In: J. B. FALIŃSKI (ed.).

Vademecum Geobotanicum 3, 537 pp. Wyd. Nauk. PWN, Warszawa.

MIREK Z., PIĘKOŚ-MIRKOWA H., ZAJĄC A. & ZAJĄC M. 2002. Flowering plants and pteridophytes of Poland. A checklist. In: Z. MIREK (ed.). Biodiversity of Poland 1, 442 pp. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

MIREK Z. & PIĘKOŚ-MIRKOWA H. 2003. Grasses of mountains in Poland. In: L. FREY (ed.). Problems of grass biology, pp. 95-118. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

POGAN E., IZMAIŁOW R. *ET AL*. 1983. Further studies in chromosome numbers of Polish Angiosperms. Part XVII. Acta Biol. Crac. ser. Botanica 25: 57-77.

POGAN E., RYCHLEWSKI J. *ET AL*. 1980. Further studies in chromosome numbers of Polish Angiosperms. Part XIV. Acta Biol. Crac. ser. Botanica 22: 129-153.

ROTHMALER W. 1995. Exkursionsflora von Deutschland. Band 3, Gefäßpflanzen: Atlasband. 753 pp. Spektrum Akademischer Verlag Heidelberg-Berlin.

SAINT-YVES A. 1934. Contribution à l'étude des *Brachypodium*. Candollea 5: 427-493.

SCHIPPMANN U. 1991. Revision der europäischen Arten der Gattung *Brachypodium* Palisot de Beauvois (Poaceae). Boissiera 45(1-7): 8-249.

SCHLÄPFER F. & FISCHER M. 1998. An isozyme study of clone diversity and relative importance of sexual and vegetative recruitment in the grass *Brachypodium pinnatum*. Ecography 21: 351-360.

SHI Y., DRAPER J. & STACE C. A. 1993. Ribosomal DNA variation and its phylogenetic implication in the genus *Brachypodium* (Poaceae). Plant Syst. Evol. 188: 25-138.

SMITH P. M. 1980. *Brachypodium* Beauv. In: T. G. TUTIN, V. H. HEYWOOD, N. A. BURGES, D. H. VALENTINE, S. M. WALTERS & D. A. WEBB (eds.). Flora Europaea, 5, pp. 189-190. Cambridge University Press, Cambridge.

ZAJĄC A. & ZAJĄC M. (eds.). 2001. Distribution atlas of vascular plants in Poland. xii+714 pp. Edited by Laboratory of Computer Chorology, Institute of Botany, Jagiellonian University, Cracow.