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Bolboschoenus yagara (Cyperaceae) newly reported for Europe

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We report the Asian species *Bolboschoenus yagara* (Ohwi) A. E. Kozhevnikov (Cyperaceae) from Europe, where only *B. maritimus* (L.) Palla has previously been recorded. Critical differences between these species lie mainly in achene structure, particularly anatomy of the pericarp, and in the persistence of the perianth bristles on the achenes, which we illustrate with SEM micrographs. We also report putative hybrids (*B. maritimus* x *yagara*) on grounds of the intermediate structure of the achenes. The presence of *B. yagara* and hybrids in Europe bears on the typification of *Scirpus maritimus* L., which is problematic. We recognize *B. affinis* (Roth) Drobov pending further research.

Key words: *Bolboschoenus affinis*, *B. maritimus*, *B. yagara*, Cyperaceae, Europe, *Scirpus*, taxonomy

INTRODUCTION

Bolboschoenus (Ascherson) Palla is herein accepted as a distinct genus following Goetghebeur and Simpson (1991). *Bolboschoenus* is taxonomically difficult (Wilson 1981, Goetghebeur & Simpson 1991), in part because of the paucity of reliable macromorphological features available for infrageneric classification. In particular, *B. maritimus* (L.) Palla is differently constituted by different workers in different parts of its range on several continents (e.g., Koyama 1958, 1980, Browning *et al.* 1995). Norlindh's (1972) valuable account for Eurasia drew

attention to the variability of the inflorescence, the number of style branches, and the shape of the achenes, all of which have been used frequently in the delimitation of *B. maritimus* or its infraspecific taxa. Because of the variability he found, Norlindh doubted the value of these characters in the definition of species. Robertus-Koster (1969) illustrated the variability in achene shape for populations in Holland. Browning and Gordon-Gray (1993), following initial work by Oteng-Yeboah (1974), showed that S African plants, previously collectively identified as *Bolboschoenus maritimus* (Browning & Gordon-Gray 1992), were divisible into two entities on the basis of gross morphology of the achenes, pericarp anatomy, and the persistence of the perianth bristles on the shed achenes. Subsequently Browning *et al*. (1995) used these criteria to help clarify the species limits within *Bolboschoenus*, including *B. maritimus*, in the area of the Flora of North America (FNA). They showed that *B. maritimus* and *B. robustus*(Pursh) Soják may be clearly distinguished from other North American species on the basis of achene structure and the non-persistence of perianth bristles on the achenes.

In W Europe, most taxonomists in recent years have recognized only one species in *Bolboschoenus*, namely, *Scirpus* (*Bolboschoenus*) *maritimus* (e.g. Ascherson & Graebner 1904, Suessenguth 1939, Hermann 1956, Schultze-Motel 1967, Robertus-Koster 1969, Casper & Krausch 1980). They included within the limits of *S. maritimus* plants with capitate to open inflorescences, bifid or trifid styles, and lenticular to trigonous achenes with caducous to attached perianth bristles. Several authors have also pointed out that *B. maritimus* occurs both in saline to brackish (maritime and inland) habitats and in fresh-water inland habitats in Europe as described by Hejny (1960), Schultze-Motel (1967), Robertus-Koster (1969) and Casper and Krausch (1980). In Flora Europaea, DeFilipps (1980) recognized only *Scirpus maritimus* but with two subspecies, namely subsp. *maritimus* with "reddish or dark brown glumes [and] nut plano-convex or trigonous", and subsp. *affinis* (Roth) T. Norlindh, with "glumes whitish-yellow, stramineous or silvery membranous [and] nut lenticular". This interpretation clearly follows that of Norlindh (1972), who stated that he considered *Scirpus affinis* Roth to be only a geographical race of *S. maritimus*. We herein recognize *Bolboschoenus affinis* (Roth) Drobov pending further research. For E Europe and Asia a greater number of species are generally recognised, but there are differences of opinion (e.g. Koyama 1958, 1980, Ohwi 1965, Egorova 1976a, 1976b, Hultén & Fries 1986, Kozhevnikov 1988); nor is the taxonomy of the genus stabilized in Africa (Browning & Gordon-Gray 1992, 1993); in North America (e.g. Browning *et al*. 1995); and in the S Pacific (e.g. Wilson 1981).

Bolboschoenus yagara (Ohwi) A. E. Kozhevnikov (basionym *Scirpus yagara* Ohwi: type from Japan, Kyoto, *Ohwi 9238*; holotype KYO, isotype TNS) has previously been reported only from Asia (Koyama 1958, 1980, Hultén & Fries 1986, Koshevnikov 1988). Koyama (1958, 1980) reduced *B. yagara* to *Scirpus* (*Bolboschoenus*) *fluviatilis* var./subsp. *yagara* and Ohwi (1965) placed it in synonymy under *Scirpus fluviatilis*. Other authors (e.g. Hultén & Fries 1986), however, treat *B. yagara* as a distinct species restricted to Asia and *B. fluviatilis* restricted to North America. In this paper we treat *B. yagara* as a species distinct from *B. fluviatilis* pending further research.

Bolboschoenus yagara, as characterised by Koyama (1958, 1980) and Ohwi (1965), differs from *B. maritimus* and *B. affinis*. Distinguishing features are outlined in the summary that follows. The differences distinguishing *B. yagara* and *B. fluviatilis* from *B. maritimus* and *B. affinis* appear to be more strongly marked in our opinion than are the differences that distinguish *B. fluviatilis* from *B. yagara* and *B. maritimus* from *B. affinis*. All these taxa require more extensive study.

Bolboschoenus yagara: Inflorescence compound or rarely head-like, usually with 3–8 branches each carrying 2 or 3 spikelets; glumes reddish to darker brown; perianth bristles rather strong, remaining attached to mature achenes, mostly ca. equalling achene; styles trifid; achenes nearly equilaterally strongly trigonous, apex tapered to a stout beak 0.2–0.6 mm long.

Bolboschoenus fluviatilis differs from *B. yagara* mainly in its larger overall plant size and in its larger achenes. Achene sizes as given by Koyama (1980) are 2.5–3.5 × 1.8–2.2 mm for *B. fluviatilis* subsp. *yagara* and 3.8–4.2 × 2.0–2.5 mm for subsp. *fluviatilis*; Browning *et al*. (1995) give 3.8–5.5 × 2.0–2.9 mm for North American *B. fluviatilis*.

Bolboschoenus maritimus: Inflorescence head-like or with 1 or 2 short branches; glumes reddish or dark brown; perianth bristles weak, caducous, to

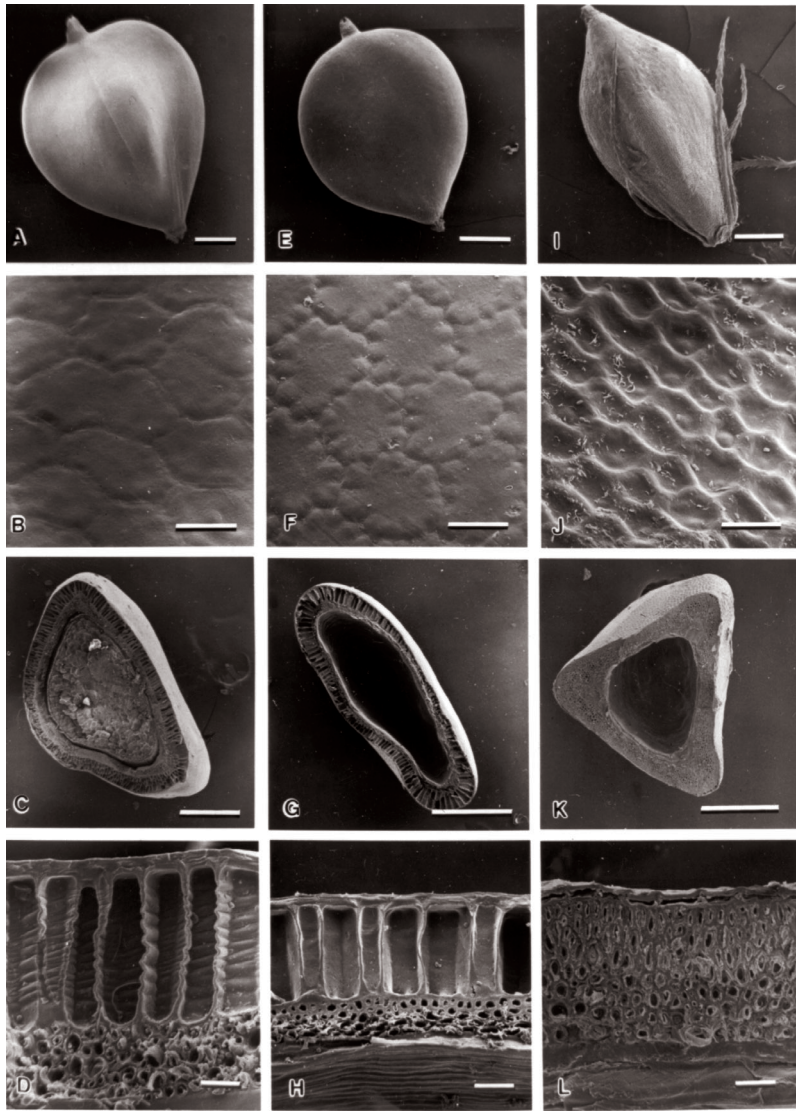

Fig. 1. Scanning electron micrographs of achenes. — A–D: *Bolboschoenus maritimus* (L.) Palla (from *Nilsson 9515*, H). — E–H: *B. affinis* (Roth) Drobov (from *Kukkonen 12727*, H). — I–L: *B. yagara* (Ohwi) A. E. Kozhevnikov (from *Baenitz II Lf. 109*, MO). — A, E, I: Abaxial views. B, F, J: Surfaces of exocarp. C, G, K: Transverse sections. D, H, L: Transverse sections of pericarp, exocarp at top. Scale bars: A, C, E, G, I, K = 500 μm. B, D, F, H, J, L = 25 μm.

about 2/3 of achene length; styles bifid, or trifid, or variable in a spikelet; achenes flattened, plano-convex to biconvex to obscurely trigonous to trigonous, apex abruptly contracted to a mucro 0.2–0.4 mm long. Almost all plants of *B. maritimus* in North America have bifid styles and plano-convex to lenticular achenes (Browning *et al*. 1995), and all of the rather few specimens we have seen from Asia and South America on which style number or achenes can be observed are digynous. In contrast, trifid styles and trigonous achenes are more common in Europe and in Africa (Browning *et al*. 1995).

According to Norlindh (1972), and our unpublished observations of a limited number of specimens, *Bolboschoenus affinis* differs from *B. maritimus* mainly in its smaller overall plant size; its pale whitish-yellow, stramineous or silvery membranous glumes (generally bright brown in *B. maritimus*); and its consistently bifid styles and lenticular achenes.

The purposes of this paper are to show 1) that *Bolboschoenus yagara* occurs in Europe; 2) that it has previously been incorporated within *B. maritimus* there; 3) that *B. maritimus* and *B. yagara* may readily be distinguished by characters of the achene surface and pericarp anatomy in addition to the gross morphological characters given above; 4) and that the problem of species differentiation in W Europe is exacerbated by the presence of putative *B. mari-*

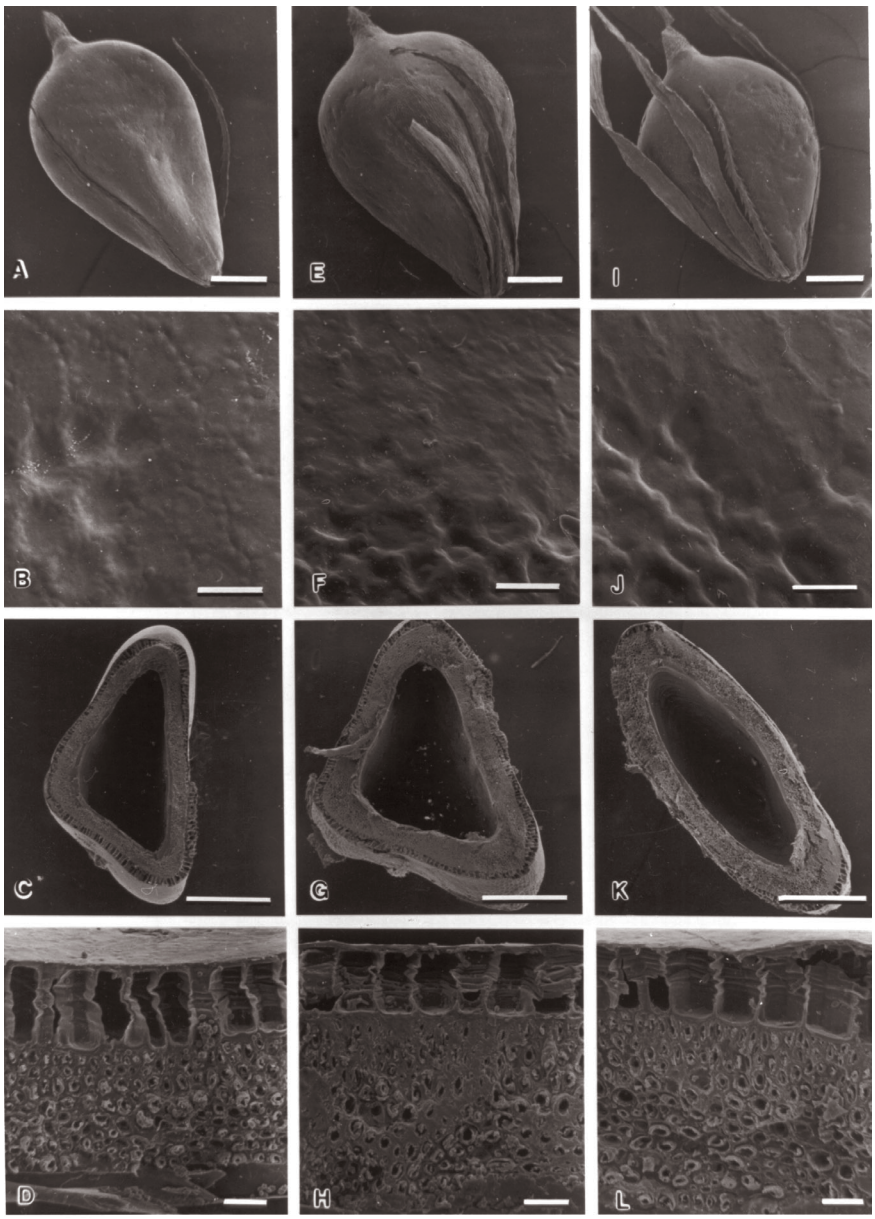

Fig. 2. Scanning electron micrographs of achenes of putative *Bolboschoenus maritimus* (L.) Palla x *yagara* (Ohwi) A. E. Kozhevnikov hybrids. — A–D: (from *Firket s.n.*, WIS) — E–L: Trigonous and lenticular achenes (from *Schuhwerk 7039/2*, NY). — A, E, I: Abaxial views. B, F, J: Surfaces of exocarp. C, G, K: Transverse sections. D, H, L: Transverse sections of pericarp, exocarp at top; endocarp not visible in H and L. Scale bars: A, C, E, G, I, K = 500 μ m. B, D, F, H, J, L = 25 μm.

timus x *yagara* hybrids which are recognizable as such on the basis of their achene morphology.

MATERIALS AND METHODS

We selected fruiting specimens labelled as *Bolboschoenus*/*Scirpus maritimus* from the Eurasian material at the following herbaria: MO, NU, NY, WIS, and in addition some fruits were provided by GENT, H and NU. We compared the European specimens with specimens from China, Japan and far E Russia, two of which Koyama identified as *B. fluviatilis* subsp. *yagara*. We studied some achenes from these specimens with dissecting microscopes and others using SEM at the University of Natal, Pietermaritzburg, according to the methods described by Browning and Gordon-Gray (1993). We identified the specimens using the diagnostic characteristics of the achenes as described by taxonomists. Data on these collections are given at the end of this paper.

RESULTS

Figs. 1 and 2 illustrate features of fruit gross morphology and pericarp anatomy of *Bolboschoenus*

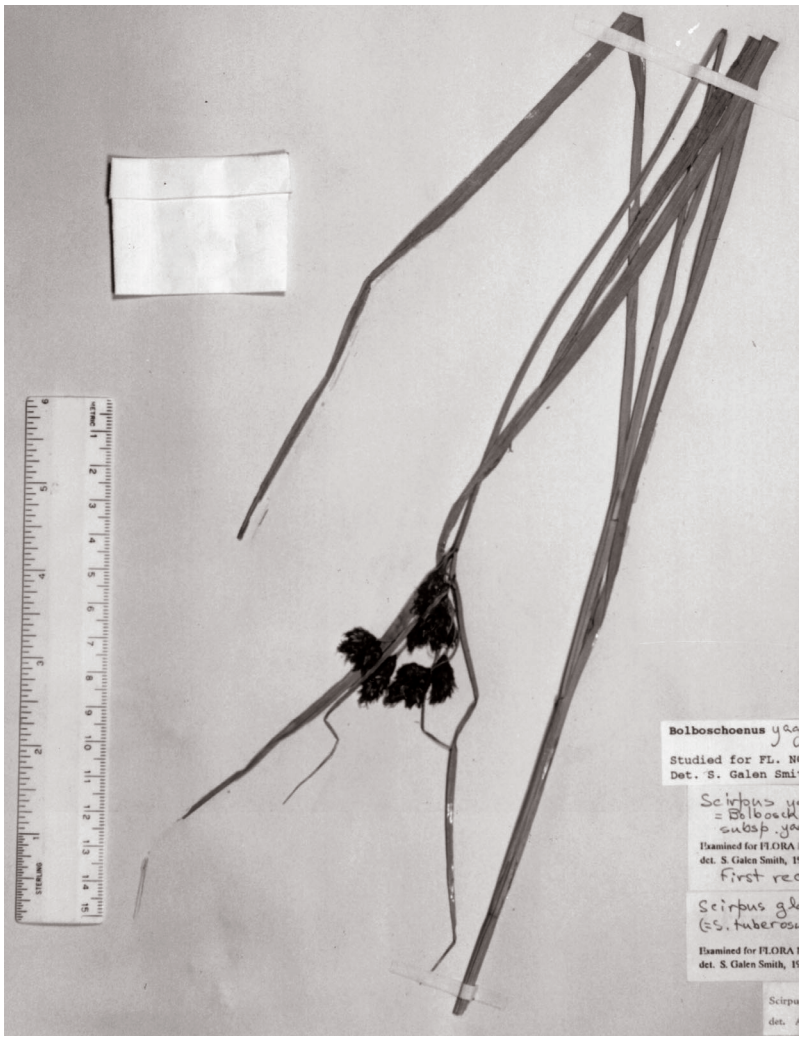

Fig. 3. Photograph of the herbarium specimen of *Baenitz II Lf. 109* (MO), from which the achene illustrated in Fig. 1 was extracted.

maritimus, *B. affinis*, *B. yagara*, and putative *B. maritimus* x *yagara* hybrids. Figs. 3 and 4 show photographs of herbarium specimens of European *B. yagara* and a putative *B. maritimus* x *yagara* hybrid. We identified the European specimens as follows:

1) Two sheets of one collection (*Baenitz Lf. II. 109*, Germany) as *Bolboschoenus yagara*. A photograph of the specimen from which we studied the achenes with SEM is shown in Fig. 3 and its achene structure is shown in the SEM micrographs in Fig. 1I–L.
2) Five specimens as putative *Bolboschoenus maritimus* x *yagara* hybrids. A photograph of one of these (*Schuhwerk 7039/2*, Germany) is shown in Fig. 4 and the achene structures of three of them are shown in Fig. 2E–L.
3) Many specimens as *Bolboschoenus maritimus*. The achene structure of one specimen (*Nilsson 9515*, Sweden) is shown in Fig. 1A–D.
4) Some specimens from Caucasia as *Bolboschoenus affinis*. The achene structure of one of these (*Kukkonen 12727*, Azerbaijan) is shown in Fig. 1E–H.

The main achene and perianth bristle characteristics of the three taxa as shown in Fig. 1 are:

1) The bristles are not persistent on the mature achenes in *Bolboschoenus maritimus* and *B. affinis* but are persistent in *B. yagara*.
2) The outline of the achenes is usually broadly

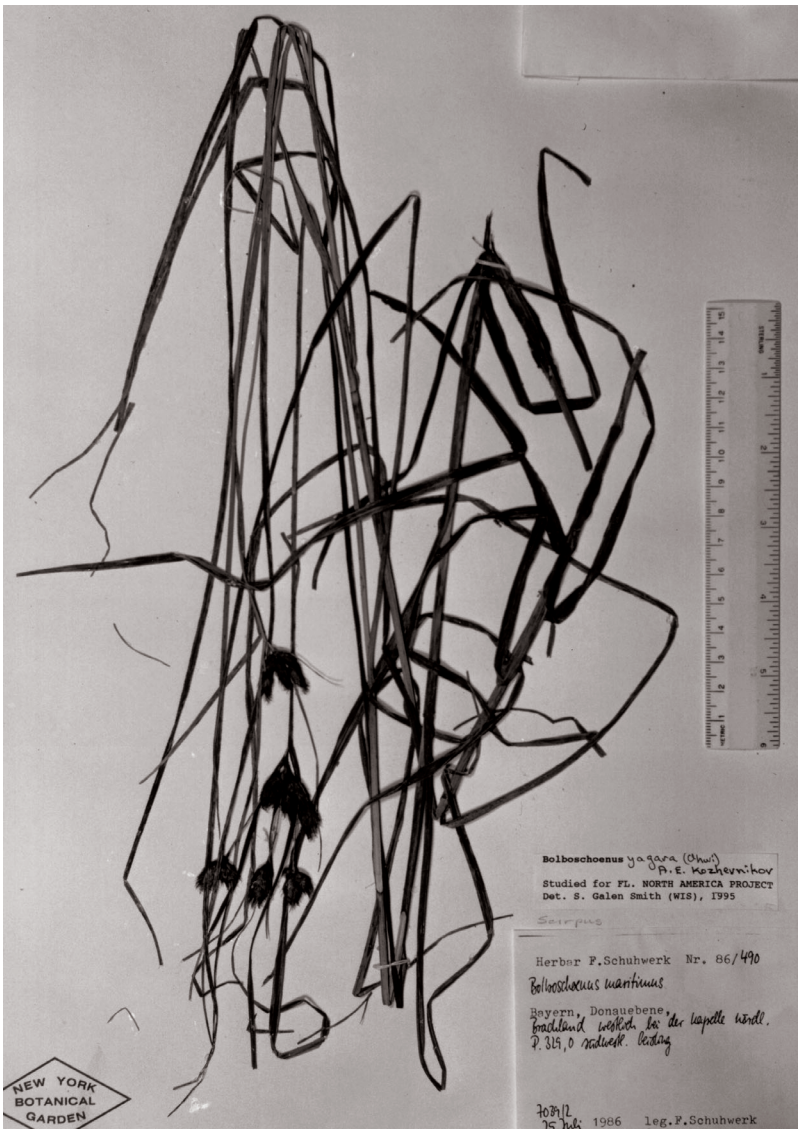

Fig. 4. Photograph of the herbarium specimen of *Schuhwerk 7039/2* (NY), from which the achenes illustrated in Fig. 2 were extracted.

obovate with summit rounded or truncate narrowing to a slender mucro in *Bolboschoenus maritimus* and *B. affinis* but is narrowly obovate with summit tapered in *B. yagara*.

3) The achenes are lenticular in *Bolboschoenus affinis*, vary from compressed-trigonous (as in the specimen illustrated herein) to lenticular in *B. maritimus*, and are nearly equilaterally trigonous in *B. yagara*.
4) Several details of the sculpturing of the achene surface differ in the three taxa.
5) In the pericarp anatomy, the exocarp (epidermis) is very deep and the mesocarp very shallow in *Bolboschoenus maritimus* and *B. affinis*, while the exocarp is very shallow and the mesocarp very deep in *B. yagara*.

The fruit gross morphology, surface features, and pericarp anatomy of putative *Bolboschoenus maritimus* x *yagara* hybrids as seen in electron micrographs (Fig. 2) are intermediate between those of *B. yagara* and *B. maritimus* as shown in Fig. 1. Note that in *Schuhwerk 7039/2* (Fig. 2E–L) both trigonous and lenticular achenes occurred; in the other four specimens the achenes examined were all trigonous.

The main characteristics of the putative hybrids as shown in Fig. 2 are:

1) The perianth bristles (Fig. 2A, E, I) are present but not always firmly attached.
2) The achene outline (Fig. 2A, E, I) is intermediate between that of *Bolboschoenus maritimus* and *B. yagara*.
3) The achene shape in transverse section (Fig. 2C, G, K) is compressed-trigonous with low rounded abaxial angle or sometimes lenticular.
4) The sculpturing of the achene surface is variable (Fig. 2B, F, J).
5) As seen in transverse section, the relative thickness of the exocarp (epidermis) and the mesocarp differ in the putative hybrids as compared with those of *Bolboschoenus maritimus* and *B. yagara* (contrast Fig. 2D, H, L with Figs. 1D, H, L.).

The main features of the inflorescences of *Bolboschoenus yagara* and putative *B. maritimus* x *yagara* hybrids are illustrated in Figs. 3 and 4.

DISCUSSION AND CONCLUSIONS

Critical differences between *Bolboschoenus maritimus* and *B. yagara* lie in their achene structure and the persistence of perianth bristles on the achene at time of its shedding from the spikelet. The following additional differences are less reliable because of infraspecific variation but are useful in making provisional identifications when specimens lack mature achenes: 1) The inflorescence in *B. maritimus* varies from capitate (branches lacking) to open with branches ca. 4 and generally with less than half of the spikelets on branches, while in *B. yagara* it is open with branches ca. 3–9 and with more than half of the spikelets on branches. 2) The summits of the leaf sheath orifices of *B. maritimus* usually have the veins diverging below the summit leaving a V-shaped membranous or hyaline area, while those of *B. yagara* have veins reaching nearly to the summit and anastomosing there.

The specimens that show intermediate achene structure (Fig. 2) we hypothesize as being *Bolboschoenus maritimus* x *yagara* hybrids. This concept is supported by the variability of the achene cross- section shape (*Schuhwerk 7039/2*), and in the achene surface. There are also differences in the relative thicknesses of exocarp and mesocarp as shown in transverse sections of the pericarp. This intermediacy is very similar to that of the achenes of the North American *B. novae-angliae* (Britton) S. G. Smith, which we hypothesized is derived from *B. fluviatilis* x *robustus* hybrids (Browning *et al.* 1995).

The presence of *Bolboschoenus yagara* and putative hybrids in Europe is especially important because all of the existing original elements (specimens and illustrations) of *Scirpus maritimus* may belong to *B. yagara* or *B. maritimus* x *yagara* hybrids or to other species. Typification will be dealt with in another paper by I. Kukkonen, S. G. Smith and others.

Fruiting specimens studied (those illustrated in scanning electron micrographs herein are indicated by SEM). —*Bolboschoenus yagara.* **Germany.** Görlitz, leg. *Baenitz*, in Nord- und Mitteldeutschlands Juncaceen und Cyperaceen Lief. 2: 109 (MO) [SEM]. **Russia.** "Fl. Amur.", *Pavlenko 2791* (MO) and *Pavlenko 5003* (MO, WIS). **China.** Kiangsu Prov., Nanking, 1922, *Merrill 11426* (NSW, NY). **Japan.** 1914, *Makino s.n.* (MO). *Putative Bolboschoenus maritimus x yagara hybrids.* **Belgium.** Bords de la Meuse à la Visé, 1872, *Firket s.n.* ex Herb. Thielens (WIS) [SEM]. **Germany.** West-Prussia, Tiegenhof, 1900, *Gross s.n.* (NY); Bayern, Donauebene, 1986, *Schuhwerk 7039/2* (NY) [SEM]; Gras-Herbarium No. 12, *Wagner s.n.* (NY); Frankfurt, 1820, *Engelmann s.n.* (MO). *Bolboschoenus maritimus.* **Finland.** Regio aböensis (Ab), Askainen, 1972, *Hinneri & Laine s.n.*(NU). **Sweden.** Gotland, Öestergarn parish, Herrvik, Natviksudden, 1994, *L.A. Nilsson s.n.* (NU); E Uppland (Roslagen), par. Börstill, 2 km W Kallö, 1995, *Ö. Nilsson 9515* (H) [SEM]. **France.** Pays-Bas, Flandre zélandaise, N Hedwige Polder, 1970, *Duvigneaud 12024* (GENT). *Bolboschoenus affinis.* **India.** W coast, "Malabar" [Kerala], "Conkan" [Konkan, Maharashtra] etc., *Stocks, Law etc., s.n.* (C, neotype). **Azerbaijan.** Hanlar, Caspian coast 10 km S Baku, *Kukkonen 12720* (H); Bejuk Sor 8–10 km N Baku, *Kukkonen 12727* (H) [SEM].

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