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The carpology and taxonomy of some Chinese *Corispermum* (Amaranthaceae s.l.)

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Abstract

Corispermum iljinii from Qinghai and Ningxia provinces and *C. nanum* from Xizang (Tibet) are described as new species. The new variety *C. dutreuilii* var. *montanum* is described. Lectotypes of *C. declinatum*, *C. elongatum* and C. *macrocarpum* have been designated. The fruit anatomy of 16 Chinese taxa has been investigated for the first time. Both molecular and carpological data support the specific status of *C. ellipsocarpum*. The general fruit structure of *Corispermoideae* is specified and discussed.

Key words: Chenopodiaceae, China, distribution, fruit anatomy, lectotypification, new taxon

Introduction

The genus *Corispermum* (Linnaeus 1753: 4) comprises at least 70 annual taxa distributed in Eurasia and North America. Central Asia appears to be one of the richest regions in *Corispermum* species. Twenty-seven species are recorded in temperate China (Zhu *et al.* 2003). All of them belong to various groups distinguished in having a perianth with 1(−2) hyaline segments. Concerning the other reproductive characters, especially in fruit morphology, the Chinese taxa highlight an high differentiation. However, their relationships have so far been insufficiently investigated, involving contradictory morphological data (Popov 1959, Klokov 1960, Mosyakin 1994, 1997), carpological investigations (Sukhorukov 2007) and recently combined molecular studies (Xue & Zhang 2011). Nevertheless, molecular phylogeny confirms the existence and distant position of at least some aggregates, such as *C. puberulum* Iljin s.str. (Iljin 1929: 645) and *C. puberulum* var. *ellipsocarpum* C.P.Tsien & C.G.Ma (Kung *et al*. 1978: 118), *C. macrocarpum* Bunge (Bunge 1859: 226) and *C. macrocarpum* var. *rubrum* Fu & Wang-Wei (Liou 1959: 84). Despite the widely accepted view that there are transitional forms between some species (Grubov 1966), or that the number of taxa in the genus might be reduced (Zhu *et al.* 2003), both fine carpology and molecular phylogeny currently reveal a considerable taxonomic diversity in the genus that can be regarded as morphologically cryptic. Among all the traditional methods, fruit anatomy appears to be pivotal for taxonomy and species delimitation when the morphological data do not allow precise identification (Sukhorukov 2007). For the majority of taxa known from China, the fruit anatomy has never been studied, and the present research is focused on filling the existing gaps in the carpology of Chinese taxa. The particular aims of our study are:

(1) taxonomic revision of the *Corispermum* specimens in Chinese collections, including lectotypifications where necessary;

(2) carpological investigations of Chinese species with reference to their taxonomy as well as precise description of the carpological characters of the genus in general.

Materials and Methods

Material preserved in the herbaria LE, MW, PE, XJA, and XJBI (herbarium abbreviations according to Thiers 2008+) was studied. One or two loose fruits from some specimens were used for the carpological analysis (see the Appendix for the

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list of the specimens used for the fruits analysis). The cross-sections were made by hand. Before cutting, the material was soaked for a few days in a solution of water, glycerin and ethyl alcohol mixed in equal proportions. According to previous investigation (Sukhorukov 2007), cross-sections of the central part of the fruit provide the most valuable information on the differences in pericarp structure. This method is also used here for the carpological analysis.

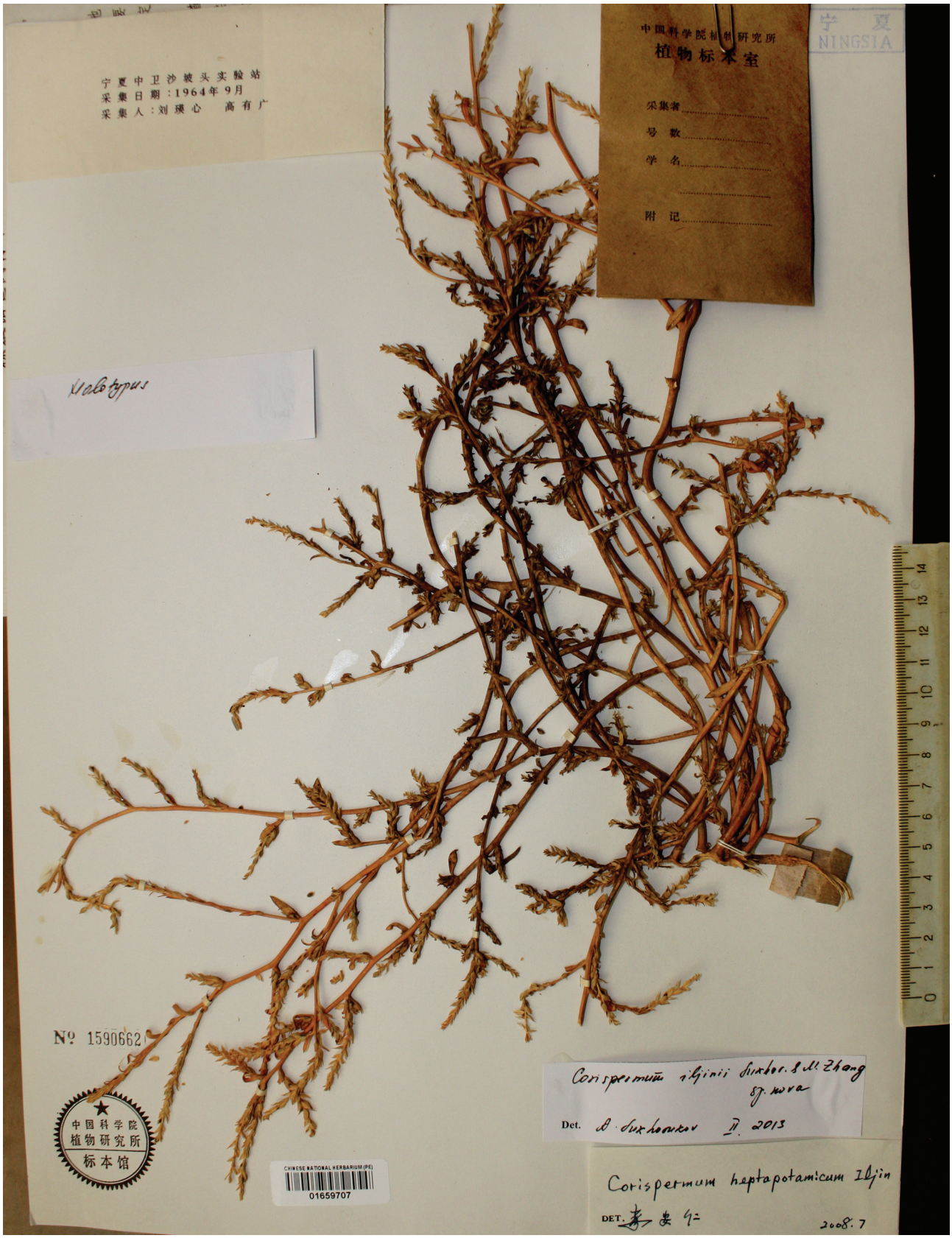

FIGURE 1. Holotype of *C. iljinii* (PE).

Results

The new taxa

Corispermum iljinii Sukhor. & M.Zhang, *sp. nov.*

Type:—CHINA. Ningxia: Zhongwei, October 1964, *Liu s.n.* (holotype PE-01659707!) (Fig. 1).

Diagnosis:—Annual to 30 cm, branched from the base, with ascending shoots, glabrous or sparsely pubescent. Leaves lanceolate or oblong, 3–5 mm wide. Spikes elongated. Bract ovoid, completely covering the fruit. Perianth of 1 segment. Fruit ovoid, 2.7–3 × 1.6–1.8 mm, fruit surface (Fig. 2) without stellate hairs but with conspicuous areas where the pericarp is detached from the seed coat (looking like warts), scattered papillae and brown pigment cells, round or acute at apex, wing not visible with the naked eye.

FIGURE 2. Fruit of *Corispermum iljinii* (SEM).

Ecology and distribution:—A label attached to additional specimens examined (Qinghai, Kokonor) contains information about the ecology of *C. iljinii*: "Plain with sparse herbs (many chenopods and grasses), some small sand dunes with denser vegetation; margins mostly planted with *Populus* or with *Hippophae* thickets, soils often incrusted with salt. Dry slopes dominated by tussocks of *Achnatherum*. Growing in open sandy areas, commonest on sand dunes". *C. iljinii* is known in the provinces Ningxia and Qinghai.

IUCN Red List Category:—The appropriate data on abundance and/or distribution of the taxon is lacking. It can be included in the Data Deficient (DD) as well as Not Evaluated (NE) categories of IUCN Red List categories (IUCN 2010) as there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution and/or population status.

Etymology:—The new species is dedicated to Modest M. Iljin (1889-1967), Professor at the Leningrad (St.-Petersburg) Botanical Institute, an expert on the Eurasian Chenopodiaceae.

Taxonomical notes:—All specimens of *C. iljinii* used to be identified as *C. heptapotamicum* or *C. declinatum*. The most remarkable character of the new species is the wart-like fruit surface with no marginal wing. The fruits resemble those of *C. tylocarpum*, but the length/width ratio is 1.5–1.7:1 (not 2:1), and also there are some differences in fruit anatomy (details provided below). The name *C. iljinii* cannot be applied to the varieties of *C. tibeticum* and *C. lepidocarpum* described by Huang (1995) from Qinghai province due to the differences in fruit characters.

Additional specimens seen (Fig. 3)**:**—CHINA. **Ningxia**: Tongxin, 13 August 1981, *Yu & Xu 1784* (PE-01659710). **Qinghai, Kokonor**: Gonghe Xian, Kyikug Xiang: along the Kyikug He river, NW of its junction with the Huang He (Yellow river), elev. 2500 m, 36°12'N, 100°43'E, heavily grazed broad plain and adjacent dry slopes, 18 September 1996, *Ho, Bartholomew, Watson et Gilbert 3095* (PE-01659709, only the specimen on the left side, the specimen on the right side belongs to *C. pseudofalcatum*).

FIGURE 3. The distribution of *C. iljinii* (dots), *C. nanum* (triangles) and *C. dutreuilii* var. *montanum* (asterisk) based on the specimens seen.

Corispermum nanum Sukhor. & M. Zhang, *sp. nov.*

Type:—CHINA. Xizang [Tibet], Saga, Nyalam road, 17 August 2011, *Yu, Hou & Zhang 5607* (holotype PE-2264191 !) (Fig. 4).

Diagnosis:—Dwarfish, densely pubescent annual up to 6 cm with single stem or with short lateral branches. Leaves linear, to 2 mm wide. Inflorescence very short producing a few flowers with a perianth consisting of one segment. Bracts slightly shorter than fruits (the fruit margins are visible). Fruit ovoid, 2.5–2.7 × 2 mm, glabrous, apex with two-fid tip, no visible detachments of the pericarp from the seed coat, marginal wing conspicuous (0.3–0.4 mm) (Fig. 5).

Ecology and distribution:—Sandy substrates in river basins. It is probably the highest-altitude representative of *Corispermum* (alt. 4000−4700 m). The species was collected from a single locality (Fig. 3) with many specimens being deposited in PE.

IUCN Red List Category:—The appropriate data on abundance and/or distribution of the taxon is lacking. It can be included in the Data Deficient (DD) as well as Not Evaluated (NE) categories of IUCN Red List categories (IUCN 2010) as there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution and/or population status.

Taxonomical notes:—The new species differs from all *Corispermum* taxa known from China and adjacent states (Iljin 1936, Grubov 1966, Zhu *et al.* 2003) by the linear leaves up to 2 mm. The fruit anatomy (Fig. 6) is similar to some other Tibetan species (*C. lhasaense*, *C. falcatum*, and *C. pseudofalcatum*), but the fruit and its wing are significantly smaller.

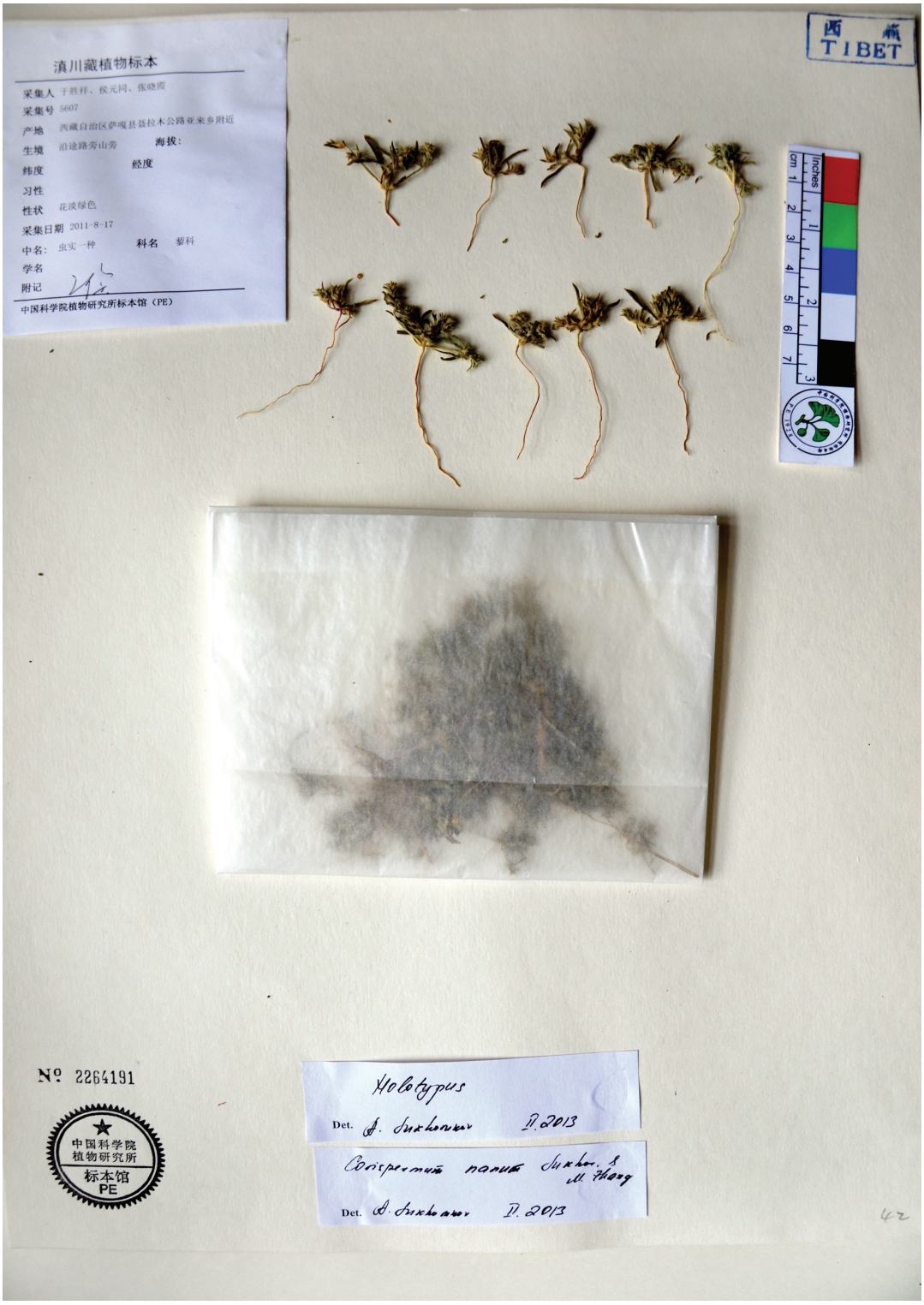

FIGURE 4. Holotype of *C. nanum* (PE).

FIGURE 5. Fruit of *Corispermum nanum*.

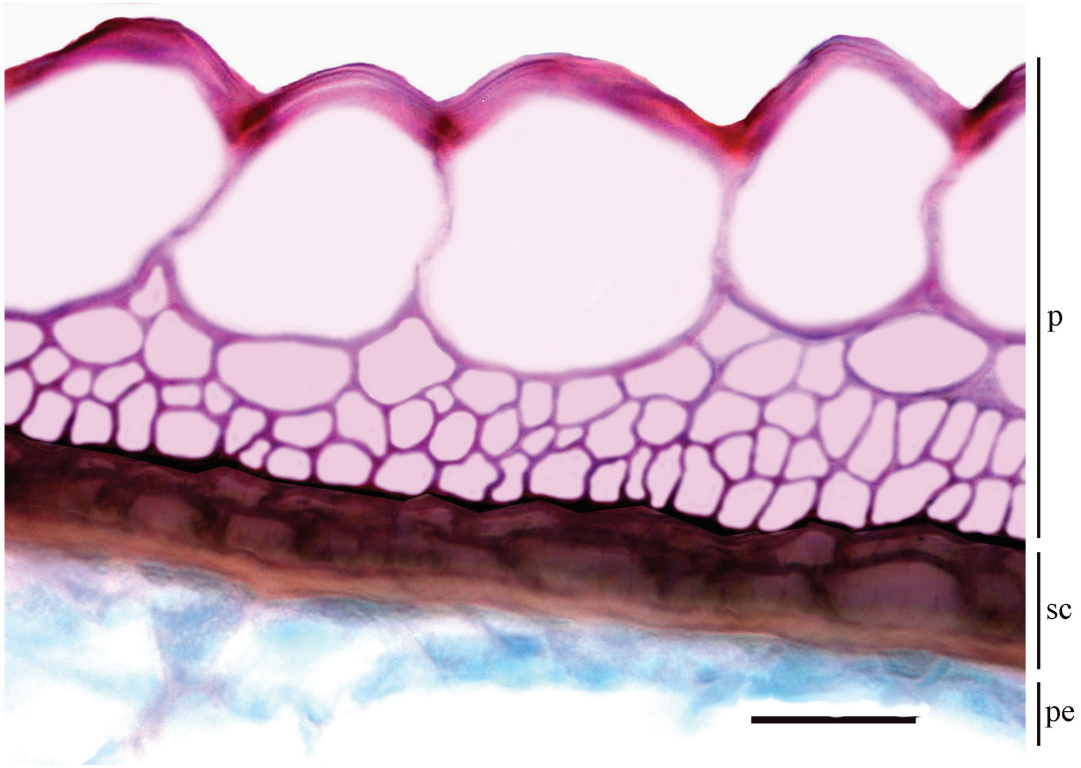

FIGURE 6. Cross-section of the fruit in its middle portion of *C. nanum*. Abbreviations: P, pericarp (presented by the thin-walled cells); sc, seed coat; pe, perisperm. Scale bar: 20 µm.

Corispermum dutreuilii Iljin var. ***montanum*** Sukhor. *var. nova.*

Type:—CHINA. Tibet [Ngari pref.] 32°31′N 80°04′E, Shiquan [Sênggê] River, alt. 3800 m, 3 August 1984, *Zhengxi An 1-10092* (holotype XJA! as *C. montanum*) (Fig. 7).

Diagnosis:—*C. dutreuilii* var. *montanum* differs from the nominal variety by the stellate pubescence and the thickness of the fruit (0.6–0.8 mm) in comparison with the type variety which has glabrous fruits with thickness 0.3–0.4 mm.

FIGURE 7. Holotype of *C. dutreuilii* var. *montanum* (XJA).

Ecology and distribution:—Sandy river basins. The new variety is known only from the *locus classicus* (Fig. 3).

IUCN Red List Category:—The appropriate data on abundance and/or distribution of the taxon is lacking. It can be included in the Data Deficient (DD) as well as Not Evaluated (NE) categories of IUCN Red List categories (IUCN 2010) as there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution and/or population status.

Taxonomical notes:—As in the nominal variety of *C. dutreuilii* Iljin (Iljin 1937), the new variety is almost glabrous, up to 25 cm tall, branched from the base. Leaves lanceolate or oblong, to 5 mm wide, bracts almost completely covering the fruits. Inflorescence loose, basally often interrupted. Fruit triangular at apex, 3.5–3.8 × 2.2 mm, with conspicuous wing 0.5–0.8 mm, with stellate pubescent fruits.

Corispermum ellipsocarpum (Tsien & Ma in Kung *et al.* 1978: 118) Sukhor. & Zhang, *comb. nova.*

Bas.: *Corispermum puberulum* (Iljin 1929: 645) var. *ellipsocarpum*.

Type:—CHINA. Hopei, Weichang co., East Mts., sands, 18 September 1960, *Wang 3066* (holotype PE-00934051!).

Taxonomical notes:—*C. ellipsocarpum* differs from C. *puberulum* by the obconical inflorescence, glabrous fruits, and details of the fruit anatomy (see carpological results below). In addition the species are nested in different clades on the molecular tree (Xue & Zhang 2011).

Lectotypification of some names in Chinese Corispermum

Corispermum declinatum Stephan ex Iljin (1928: 69).

Type (lectotype here designated by Sukhorukov & Zhang):—RUSSIA. Sibiria: *Sievers 788* (LE!, specimen on the left side).

Notes:—There is one sheet at LE, bearing one whole plant (left-hand specimen) and a small fragment (right-hand specimen) that are not part of a single gathering, so the Art. 9.17 of the ICN (McNeill *et al.* 2012) cannot be applied. We here choose the left-hand specimen and designated in as the lectotype of the name *Corispermum declinatum*.

Corispermum elongatum Bunge in Maxim., Prim. Fl. Amur.: 224 (1859).

Type (lectotype, here designated by Sukhorukov & Zhang):—RUSSIA. Amur: sandy bank of Amur river near Khungar, 11 July 1855, *Maximowicz s.n.* (LE!).

Notes:—Eleven sheets that are part of the original material are preserved at LE, each bearing one plant whose features [leaves elongated (the lower ones up to 8 cm long), linear or lanceolate, inflorescence interrupted, and fruits glabrous with conspicouos wing] match the diagnosis. We here designated the specimen collected by Maximowicz in the locality Amur since it is included in the description of *C. elongatum* (Bunge 1859).

Corispermum macrocarpum Bunge in Maxim., Prim. Fl. Amur.: 226 (1859).

Type (lectotype, here designated by Sukhorukov & Zhang):—RUSSIA. Amur: 20 September 1854, *Maximowicz s.n.* (LE!).

Notes:—Iljin (1936) and some electronic resources (e.g., IPNI 2013) indicate that *C. macrospermum* Trautvetter (1884: 130) is a nomenclatural synonym of *C. macrocarpum*. However, Trautvetter (1884) did not describe *C. macrospermum* as a separate species, and the epithet "macrospermum" is indeed a typographical error (see also correct citation in Trautvetter 1884: 130, "*C. macrospermum* [*macrocarpum*] *Bunge in Maxim*[*owicz*])."

New data on the Chinese Corispermum species

The fruit anatomy of 22 taxa was studied in the present investigation, of which 16 were carpologically analyzed for the first time (Table 1). The specimen of *C. retortum* W.Wang & P.Y.Fu (Liou 1959: 82) at LE, chosen for carpological examination cited in the previous data (Sukhorukov 2007), was erroneously identified, and now we provide corrected parameters about the carpology of this species. The carpological characters for the remaining taxa correspond with the earlier data taken from other locations (Sukhorukov 2007).

TABLE 1. The most conspicuous fruit characters of the *Corispermum* taxa studied

	Fruit length-width-thickness (mm)	Hairs on the pericarp surface	Papillae on pericarp	Pericarp detachments (μm)	Thickness of outer pericarp layer (μм)	Number of macrosclereid layers in central part of fruit	Wing shape and length in cross-section (mm)
C. candelabrum	5 × 3 × 0.55–0.7	+	–	–	20–30	1-2 outer, 2 inner	(narrowly) triangular, 0.8–0.9
**C. chinganicum* var. *stellipile*	5 × 3 × 0.55–0.7	+	–	small	20-25	0–1 outer, 2(3) inner	triangular, 0.3–0.5
**C. dilutum*	4 × 3.2 × 0.6–0.7	–	–	–	25–37	(0)1 inner	narrowly triangular, 0.5
**C. dilutum* var. *hebecarpum*	4 × 3.5 × 0.6–0.7	+	–	–	20–30	1–2 inner	narrowly triangular, 0.6–0.8
C. dutreuilii	3–4.2 × 2 × 0.35–0.4	–	–	+ (to 100)	25–40	0–1 outer, 1–2 inner	triangular, 0.3–0.4
**C. dutreuilii* var. *montanum*	3.5–3.8 × 2.2 × 0.65-0.8	+	–	(to 50)	37–50	1–2 inner	triangular, 0.3–0.4
C. falcatum	3.5 × 3 × 0.6-0.65	–	–	–	40–50	1–2 inner	narrowly triangular, 0.45–0.6
**C. huanghoense*	5 × 4 × 0.75–0.8	+	–	–	20–30	1–2 outer, 2–3 inner	narrowly triangular, 1.0–1.2
**C. iljinii*	2.7–3 × 1.6–1.8 × 0.4–0.5(0.7)	–	+	+ (to 50)	25–50 (papillae to 75)	outer 0–1, inner 1–2 inner	broadly triangular, 0.15–0.2
**C. lhasaense*	4–4.5 × 3–3.5 × 0.75–0.85	–	–	–	30–60	inner 1–3	triangular, 0.65–0.9
**C. macrocarpum* var. *microstachyum*	4–4.5 × 3–3.5 × 0.5-0.6	–	–	+ (to 130)	37–50	0–1 inner	narrowly triangular, 0.5–0.7
**C. macrocarpum* var. *rubrum*	4.3 × 3.5 × 0.65–0.8	–	–	+ (to 130)	20–30	1 inner	narrowly triangular, 0.9–1.0
**C. nanum*	2.5–2.7 × 2.0 × 0.35–0.45	–	–	–	25–30	(0)1 inner	triangular, 0.3–0.4
C. pamiricum	3.0 × 2.0 × 0.65–0.8	–	–	–	25–35	1–2 inner	broadly triangular, 0.25–0.3
**C. pamiricum* Iljin var. *pilocarpum*	2.6–3.2 × 2.0 × 0.4–0.6	+	–	+ (to 80)	20–50	1–2 inner	broadly triangular, 0.15–0.3
C. patelliforme	3.8–4.5 × 3.5–4 × 0.5-0.6	–	–	–	65–100(–125)	inner (0–)1	broadly triangular or triangular 0.3–0.4
**C. praecox*	3.8–4.5 × 3–3.2 × 0.45–0.65	+	–	–	30–40	0–1 outer, 1–2 inner	narrowly triangular, 0.5–0.7
**C. pseudofalcatum*	4.5–5.5 × 3.5–4.3 × 0.7–1	–	–	–	12–25	1–2 inner	narrowly triangular, (0.7)0.9–1.4
C. puberulum	3.5-4.2 × 2.7-3 × 0.3-0.55	+	–	+ (to 130)	20–30	(0)1–2 inner	triangular, 0.4–0.6
**C. puberulum* var. *ellipsocarpum*	4–4.5 × 2.8–3.5 × 0.5-0.7	–	–	–	25–40	0–1(2) inner	narrowly triangular, 0.5–0.8
**C. retortum*	3.5–3.7 × 2.4–2.5 × 0.5–0.6	–	–	–	25–40	(0)1(2) inner	narrowly triangular, 0.4–0.6
**C. stenolepis*	4–4.5 × 3.8–4.4 x 0.6–0.7	+	–	–	25–37	1(2) outer, 1–2(3) inner	narrowly triangular, 1.2–1.6(–2.0)

Discussion

Do anatomical data confirm the suggested relationship of the Chinese taxa based on fruit morphology?

Relationships between Chinese *Corispermum* taxa based on the assumption that only fruit-morphology provides the most important visual diagnostic characters have been proposed many times (Popov 1959, Mosyakin 1994, 1997).

However, these morphological conclusions should be considered as rather speculative owing to the similarity of fruit outlines in some taxa with differing anatomy and occupying different positions in molecular trees (Sukhorukov 2007, Xue & Zhang 2011). Despite the impossibility of preparing a global molecular phylogeny of the genus due to the inaccessibility of some plant material, we used carpological data to compare the relationships of some taxa that were not included in previous carpological discussions (Sukhorukov 2007). These comparisons are given in the Table 2.

TABLE 2. Comparison of relationships between taxa based on morphological data proposed by other authors and our carpological results.

	Baranov (1969a, 1969b)	**Tsien & Ma (in Kung *et al.* 1976)**	**Zhu *et al.* (2003)**	**Carpological results (present investigation)**
C. chinganicum var. *stellipile*	–	differs from type variety in fruit pubescence	*C. chinganicum* s.l.	differs from type variety in many characters (fruit length and thickness, pubescence, wing length, sclereid layers)
C. dilutum var. *hebecarpum*	–	differs from type variety in fruit pubescence	*C. dilutum* s.l.	closely related to *C. dilutum* s.str., differs in pubescent fruits and larger wing
C. huanghoense	–	–	related to *C. candelabrum*	differs from *C. candelabrum* in wing length and pericarp detachments
C. lhasaense	–	related to *C. falcatum*	related to *C. falcatum*	related to *C. falcatum* and *C. pseudofalcatum*
C. *macrocarpum* var. *microstachyum*	–	–	*C. macrocarpum* s.l.	related to *C. macrocarpum*, but with smaller wing and easily visible pericarp detachments
C. *macrocarpum* var. *rubrum*	–	–	*C. macrocarpum* s.l.	related to *C. macrocarpum*, but with pericarp detachments
C. pamiricum var. *pilocarpum*	–	differs from type variety in fruit pubescence	*C. pamiricum* s.l., probably synonym of *C. gelidum*	closely related to *C. pamiricum* s.str.; both differ from *C. gelidum* in the wing outline in cross-section
C. praecox	–	–	might be related to *C. tylocarpum*	not related to *C. tylocarpum*
C. pseudofalcatum	–	related to *C. falcatum*	related to *C. falcatum*	both species have the same carpology; differ from each other in fruit dimensions, thickness of outer pericarp layer, and larger wing
C. puberulum var. *ellipsocarpum*	–	differs from type variety in glabrous fruits and length of wing	*C. puberulum* s.l.	the same characters as in Tsien & Ma, and absence of pericarp detachments
C. retortum	close to *C. marschallii*	–	close to *C.* sect. *Pallasiana* (*C. leptopterum*, *C. sibiricum, C. bardunovii*, *C. macrocarpum* and North American species)	not related to *C. marschallii*, *C. leptopterum*, *C. sibiricum* or *C. bardunovii*

The differences among some infraspecific taxa are indeed greater than that indicated earlier, especially *C. chinganicum* Iljin (1929: 648) var. *stellipile* C.P.Tsien & C.G.Ma (Kung *et al.* 1978: 118) and *C. puberulum* var. *ellipsocarpum,* which are described on the basis of presence/absence of stellate indumentum on the pericarp surface. Although the hairness of the fruit was previously considered as a character with good taxonomic value at infraspecific level (Kitagawa 1935, Baranov 1969a, 1969b, Zhu *et al.* 2003), it can be taxonomically more convenient in the cases where additional carpological details are available. In the case of both *C. puberulum* s.s. and *C. puberulum* var. *ellipsocarpum*, there is a complex of data supporting separate positions of the two taxa: (1) nesting in different clades of the ML molecular tree (Xue & Zhang 2011), (2) several characters (different inflorescence shape, pericarp indumentum, fruit thickness, presence of pericarp detachments, length of fruit wing). All these details provide good reasons to raise the variety *C. puberulum* var. *ellipsocarpum* to specific rank (as *C. ellipsocarpum*).

General conclusions about the fruit anatomy of Corispermum

All recognized *Corispermum* species have now been studied carpologically, and the additional material investigated in the present article did not reveal any substantial differences in the fruit anatomy of the genus. The analysis of the Chinese material allowed us to make more precise some general fruit characters given by Butnik (1981)

and Sukhorukov (2007, 2009), especially the occurrence of large air cavities (up to 400 μm) between the pericarp and the seed coat in the species having a smooth (not wave-like) pericarp with a well-developed wing [especially *C. huanghoense* C.P.Tsien & C.G.Ma (in Kung *et al*. 1978: 118), *C. pseudofalcatum* C.P.Tsien & C.G.Ma (in Kung *et al*. 1978: 119)]. This characteristic has been evolved only in 'winged' *Corispermum* in contrast to the similar fruits of all spacies belong to *Anthochlamys* Fenzl (1837: 300) (Sukhorukov & Konstantinova 2012). We can also conclude that the well developed wing (more than 0.6–0.7 mm long) occurs in all taxa always thin and narrowly triangular in cross-section. On the other hand the short-winged (up to 0.3 mm) taxa have broadly triangular fruit margins. The average wing length appears to be triangular in cross-section.

In contrast to other Chenopodiaceae, which are often heterocarpous or heterospermous, the fruits and seeds of *Corispermum* species seem to be monomorphic. This can be explained by the reduction of 3- or several-flowered cymes to solitary flower. It is well known that the different types of morphological and anatomical fruit/seed heteromorphism have evolved within one cyme in at least a part of the Chenopodioideae (Kondorskaya 1983, Veselova & Kondorskaya 1990) or Suaedoideae (Iljin 1936). In *Corispermum* (as well as in other Corispermoideae) the solitary flowers are aggregated in spikes with no differences in the developmental stages of the flowers within the partial inflorescences. In general the subfamily *Corispermoideae* Raf. is distinguished from other family members in having the pericarp divided into two different topographical zones: parenchymatous uppermost layers and sclerenchyma below, without any crystalliferous layers in the fruit wall (see Sukhorukov 2008, Kadereit *et al*. 2010, Sukhorukov & Zhang 2013, Sukhorukov *et al.* in prep.). The similar pericarp structure in one of two heterocarpic types in *Axyris* Linnaeus (1753: 979) (Chenopodioideae-Axyrideae: Sukhorukov 2005, 2011) is a synapomorphic trait which has arisen independently in the Corispermoideae and Chenopodioideae subfamilies. The seed coat of the Corispermoideae is thin, mostly up to 10 μm, and consists of 2(−3) equal or subequal [*Agriophyllum* Bieberstein (1819: 6)] layers filled with tannins but without stalactites in the outer cell walls of the testa (the outer seedcoat layer).

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APPENDIX

The fruit anatomy of the taxa marked with an asterisk have been studied for first time.

C. candelabrum Iljin: Beijing, Marco Polo Bridge, 18 August 1962, *C. C.P. Tsien & C.G. Ma 011* (PE-00540111);

**C. chinganicum* Iljin var. *stellipile* C.P.Tsien & C.G.Ma: 1) Nei Mongol, Erdos, September 1956, *X.Z. Lang 285* (PE-00934046, holotype); 2) Henan, Fengqiu, June 1965, *D.D. Xu 106* (PE-00640929);

**C. dilutum* (Kitag.) C.P.Tsien & C.G.Ma: Liaoning, Zhangwu, October 1952, *S.E. Liu 5420* (PE-01898113);

**C. dilutum* (Kitag.) C.P.Tsien & C.G.Ma var. *hebecarpum* C.P.Tsien & C.G.Ma: Nei Mongol, Chifeng, September 1952, *S.E. Liu 5146* (PE-01801947);

C. dutreuilii Iljin: 1) S Xinjiang, VII.1961, anonym (XJBI-071080); 2) S Xinjiang, Yutian, alt. 2400 m, July 1991, Guiling Zhou *HT-015* (XJA-00035450);

C. dutreuilii Iljin var. *montanum* Sukhor.: Tibet, [Ngari pref.] 32°31′N 80°04′ E, Shiquan [Sênggê] River, August 1984, *Zhengxi An 1-10092* (XJA);

C. falcatum Iljin: Xizang, Naidong, alt. 3650 m, July 1975, *Z.Y. Wu 75-758* (PE-00540347);

**C. huanghoense* C.P.Tsien & C.G.Ma: Henan prov., Fengqiu, June 1965, *D.D. Xu 68* (PE-00540368);

**C. iljinii* Sukhor. & M.Zhang: 1) Ningxia, Zhongwei, September 1964, *Y.X. Liu s.n.* (PE-01659707 – holotype); 2) Ningxia, Tongxin, August 1981, *Z.Y. Yu 1784* (PE-01659710); 3) Qinghai, Gonghe Xian, September 1996, *T.N. Ho & al. 3095* (PE-01659709);

**C. lhasaense* C.P.Tsien & C.G.Ma: 1) Xizang, Lhasa, September 1960, G.X. Fu *658* (PE-00540404); 2) Xizang, Lhasa, September 1960, G.X. Fu *658* (PE-00024043, holotype);

**C. macrocarpum* Bunge var. *microstachyum* P.Y.Fu & W.Wang: Liaoning, Zhangwu, October 1952, S.E. Liu *5420* (PE-00024036);

**C. macrocarpum* Bunge var. *rubrum* P.Y.Fu & W.Wang: Liaoning, Zhangwu, October 1952, *S.E. Liu 5407* (PE-00024044, isotype);

**C. nanum* Sukhor. & M.Zhang: Xizang, Saga, Nyalam road, August 2011, *S.X. Yu, Y.T. Hou & X.X. Zhang 5607* (PE, holotype);

C. pamiricum Iljin: 1) Xizang, Lazi, August 1961, J.W. Zhang *2727* (PE-00540414); 2) Qinghai, Kokonor lake, July 1975, *B.Z. Guo & W.Y. Wang 11699* (PE-01801973);

**C. pamiricum* Iljin var. *pilocarpum* C.P.Tsien & C.G.Ma: 1) Xizang, Ritu, August 1976, Qingzang Team *13656B* (PE-00640936, holotype); 2) Xizang, Ritu, alt. 4300 m, August 1976, Qingzang Team *76-9128* (PE-00540419); 3) Xinjiang, Tashkurgan, July 1991, *Guiling Zhou HT-015* (XJA-00035441);

C. patelliforme Iljin: 1) Ningxia prov., Kokoputu, September 1933, *Y.Y. Pai 221* (PE-00540424); 2) Gansu prov., August 1956, *H.W. Kung s.n.* (PE-00540429);

**C. praecox* C.P.Tsien & C.G.Ma: 1) Henan, Kaifeng, June 1932, K.S. Hao *3442* (PE-00540371); 2) Henan prov., Fengqiu, June 1965, *C.X. Xu et al. 108* (PE-00934049 & PE-00540436, holotype & isotype, respectively);

**C. pseudofalcatum* C.P.Tsien & C.G.Ma: Xizang, Shigatse, August 1960, *G.X. Fu 789* (PE-00934050);

C. puberulum Iljin: Heilongjang prov., Qiqihar, October 1955, *G.Z. Wang & Z.H. Zhang 4189* (PE-00540438);

**C. puberulum* Iljin var. *ellipsocarpum* C.P.Tsien & C.G.Ma: Hepei, Chengde, September 1962, *W. Wang 3066* (PE-00934051);

**C. retortum* W.Wang & P.Y.Fu: Heilongjang prov., Duerbote, September 1951, D.C. Zhao & *Y.L Zhang et al. 973* (PE-00024046);

**C. stenolepis* Kitag.: 1) Kirin, Tongyu, August 1960, J.X. Ye *384* (PE-00540464); 2) Nei Mongol, Chifeng, October 1960, *W. Wang 3395* (PE-00540468).