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Taxonomic notes on the *Hedysarum gmelinii* complex (Fabaceae)

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A taxonomic revision of *Hedysarum* species (Fabaceae) recognized as a part of the *H. gmelinii* complex is presented. One widespread species is recognized here and two new combinations are proposed: *H. gmelinii* var. *dahuricum* (Turcz. *ex* B. Fedtsch.) R. Sa and *H. gmelinii* var. *setigerum* (Turcz. *ex* Fisch. & Mey.) R. Sa, based on morphological studies of herbarium specimens and seed coat sculpturing characteristics. The name *H. gmelinii* is lectotypified. A taxonomic conspectus for the three taxa, including a list of synonyms, information on type specimens, morphological differentiation, ecological characteristics, and distribution data are given. Additionally, the problems of former treatments of sections *Multicaulia* and *Subacaulia* within *Hedysarum* are discussed.

Key words: Fabaceae, *Hedysarum gmelinii* complex, morphology, taxonomy

Introduction

The genus *Hedysarum*, established by Linnaeus (1753), belongs to the tribe Hedysareae of the family Fabaceae. The genus is represented by ca. 100 species (Polhill 1981), most of which are distributed in temperate regions of the northern hemisphere, with the greatest diversity in central Asia and Qinghai-Tibet Plateau. Since the plants occur in a wide range of climatically diverse habitats, such as cold or dry (or cold and dry) alpine, arctic or lowland desert formations, stony scrub and grasslands, or sandy seashore dune vegetation, the morphological diversity (of both geno- and phenotypic origin) increases the taxonomic problems and makes the circumscription and delimitation of species or infraspecific groups difficult. It is worth noting that the three related taxa of the group discussed here have special economic importance as forage: *H. gmelinii*, *H. dahuricum*, and *H. setigerum*.

Hedysarum gmelinii is a widespread and morphologically variable species, distributed from northern Asia (Siberia) to central Asia and ranging across most parts of northern China (Fig. 1). The morphology is extremely variable correspondingly with its wide-ranging distribution and diverse habitats. The species mostly

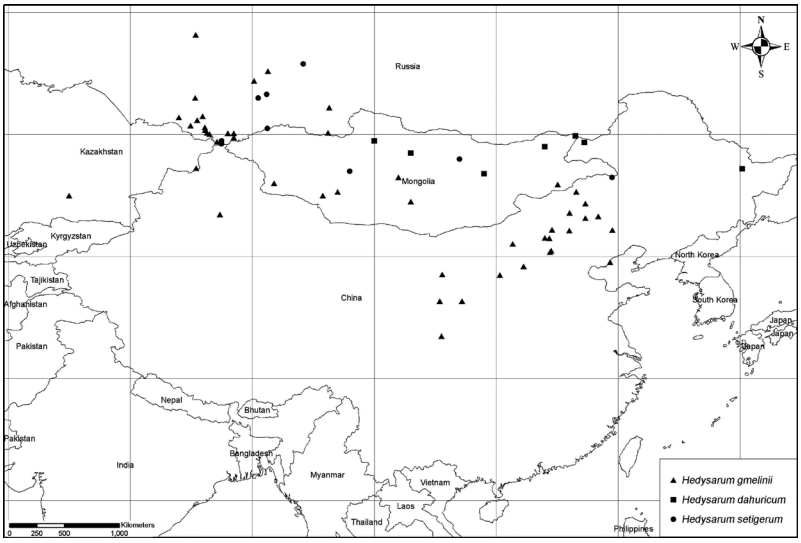

Fig. 1. The geographical distribution of the *Hedysarum gmelinii* complex.

occurs in alpine meadows and stony steppes at 800–2400 m. Herbarium specimens have mostly been identified on the basis of the species' ranges rather than morphological comparisons and analyses (Fedchenko 1948).

Hedysarum dahuricum is native to E Siberia, Mongolian Dahuria, and NE China (Fig. 1), growing in stony steppes at 600–700 m a.s.l.. It is distinguished from *H. gmelinii* only by its yellow petals, whereas *H. gmelinii* has purple petals.

Hedysarum setigerum is limited to eastern Siberia and Mongolian Dahuria (Fig. 1). Some references cite *H. setigerum* as growing on sandy steppes at 1800–2350 m a.s.l. in NE China as well; however, during our field work and specimen study we failed to find specimens at these sites. *Hedysarum setigerum* is distinguished from *H. gmelinii* by its inconspicuous stem internodes or absence of above-ground stems.

The above three taxa have similar floral and fruit morphology, and their phenology is also similar (flowering season is June to August and fruit-maturing time is July to August). Morphological characters for separation of the three taxa appear insufficient, thus their identifications were questionable, both during field identification and subsequent publication. The available data in the literature was clearly not reliable. *Hedysarum dahuricum* and *H. setigerum* were sometimes recognized at species level, while in other cases at infraspecific level or regarded as being conspecific. This is well reflected by annotations of the same herbarium specimens; Fedchenko (1902) subsumed *H. setigerum* with *H. gmelinii*, but later considered the taxon a separate species (Fedchenko 1948); Fu Hiangchian (1989) considered both *H. setigerum* and *H. dahuricum* synonymous with *H. gmelinii*, while Kurbatski (1994) found *H. setigerum* to be a subspecies of *H. gmelinii*. It appeared that in contrast to "static (herbarium) morphology" less attention had been paid so far to study of the morphological variation of the three taxa over their entire distribution.

The genus *Hedysarum* was first divided by de Candolle (1825) into two sections, based on seed-pod morphology; the system was further developed by Basiner (1845), Fedchenko (1899, 1902), and Choi and Ohashi (1996, 2003). Though Fedchenko's system had often been pointed out as unnatural (Rollins 1940, Thunlin 1985, Choi & Ohashi 1996, Choi *et al*. 1999), it was widely adopted in subsequent works (Fedchenko 1948, Chrtková 1968, Xu 1998). Sections *Multicaulia* and *Subacaulia* are very similar in floral, seed, pollen (Choi & Ohashi 1996), and anatomical characters (Choi *et al*. 1999); however, sect. *Subacaulia* has been distinguished solely by its short-stemmed or acaulescent habit with short internodes (Fedchenko 1902, 1948). No other diagnostic charac-

ters supported the segregation of these two sections. Choi and Ohashi (2003) conducted a comprehensive morphological study, including synthesis of the chemistry and distribution patterns of flavonoids (Choi 1994), palynological features (Ferguson & Skvarla 1981, Choi & Ohashi 1996), and anatomical characteristics (Choi *et al*. 1999). They simultaneously improved the infrageneric classification of the genus, combining sect. *Multicaulia* and sect. *Subacaulia* into sect. *Multicaulia* and further dividing the latter into subsect. *Multicaulia* and subsect. *Subacaulia*, respectively. However, the distinction between the two sections is still confusing.

The present study focuses on the *Hedysarum gmelinii* group, with three closely related taxa: *H. gmelinii*, *H. dahuricum*, and *H. setigerum*, of which the first two are ascribed to sect. *Multicaulia* and the last to sect. *Subacaulia* (Fedchenko 1902, 1948, Xu 1998). We aim to not only better delimit the three closely related taxa, but also to better understand the relationships between sections *Multicaulia* and *Subacaulia*.

Material and methods

The authors thoroughly examined the specimens from PE, WUK, KUN, HIMC, IMDC, FGC, NMAC, LZD, ALTB, LE, NS, and UBA. Also the types of the three studied taxa, which are deposited at LE, were consulted. The distribution data was obtained mainly from herbarium specimens, which were critically evaluated by the authors. The distribution map was created with the ArcView GIS software. The seed coat sculptures of the three taxa and some representatives (Table 1) of sect. *Multicaulia* and sect. *Subacaulia* were examined under SEM (Hitachi S-800).

Results and discussion

We found that the flowers of *Hedysarum gmelinii* are usually purple and sometimes purple with yellow or yellowish patches, whereas in *H. dahuricum* the petals are usually yellow and sometimes yellow with purple patches; therefore, the color variation is not a useful character for identification. There are overlaps in stem characters as well: *H. gmelinii* sometimes has short stems, while *H. setigerum*, though typically short-stemmed, is sometimes relatively long-stemmed. Generally one can state that stem-length in *Hedysarum* is not typically a distinctive enough character for separating species or even sections; e.g. *H. denticulatum* (sect. *Subacaulia*) typically has short stems but sometimes has elongate internodes, whereas *H. pseudoastragalus* (sect. *Obscura*) typically has longer stems but can be a dwarf plant as well (Choi & Ohashi 2003). The distribution pattern of the species showed clear correlations with

Table 1. Vouchers observed under SEM for seed coat sculptures.

Species	Fedchenko's (1902) system	Choi *et al.*'s (2003) system	Vouchers
H. brachypterum	Sect. *Multicaulia*	Sect. *Multicaulia* Subsect. *Multicaulia*	*YW Tsui s.n.*, 8 Aug. 1949; Zhangbei County, Hebei Province (PE)
H. dahuricum	Sect. *Multicaulia*	Sect. *Multicaulia* Subsect. *Multicaulia*	*Sino-Germany Team 8353*; 21 Aug. 1956; Haila'er City, Inner Mongolia (PE)
H. dasycarpum	Sect. *Multicaulia*	Sect. *Multicaulia* Subsect. *Multicaulia*	*Koroleva A. s.n.*; 30 Jul. 1970; Jakutskaja ASSR (NS)
H. gmelinii	Sect. *Multicaulia*	Sect. *Multicaulia* Subsect. *Multicaulia*	*Shansi Team 471*; 8 Aug. 1953; Shuozhou City, Shaansi Province (PE)
H. jaxartucirdes	Sect. *Subacaulia*	Sect. *Multicaulia* Subsect. *Subacaulia*	*R.C. Ching 1605*; 8 Aug. 1956; Qinghe County, Xinjiang Province (PE)
H. setigerum	Sect. *Subacaulia*	Sect. *Multicaulia a* Subsect. *Subacauli*	*Shmakov A.I. et al. s.n.*; 28 Aug. 1995; Altai (ALTB)
H. splendens	Sect. *Subacaulia*	Sect. *Multicaulia* Subsect. *Subacaulia*	*V.I. Vereshatin s.n.*; 7 Jun. 1999; Semipalatinskaja Obl. (NS)

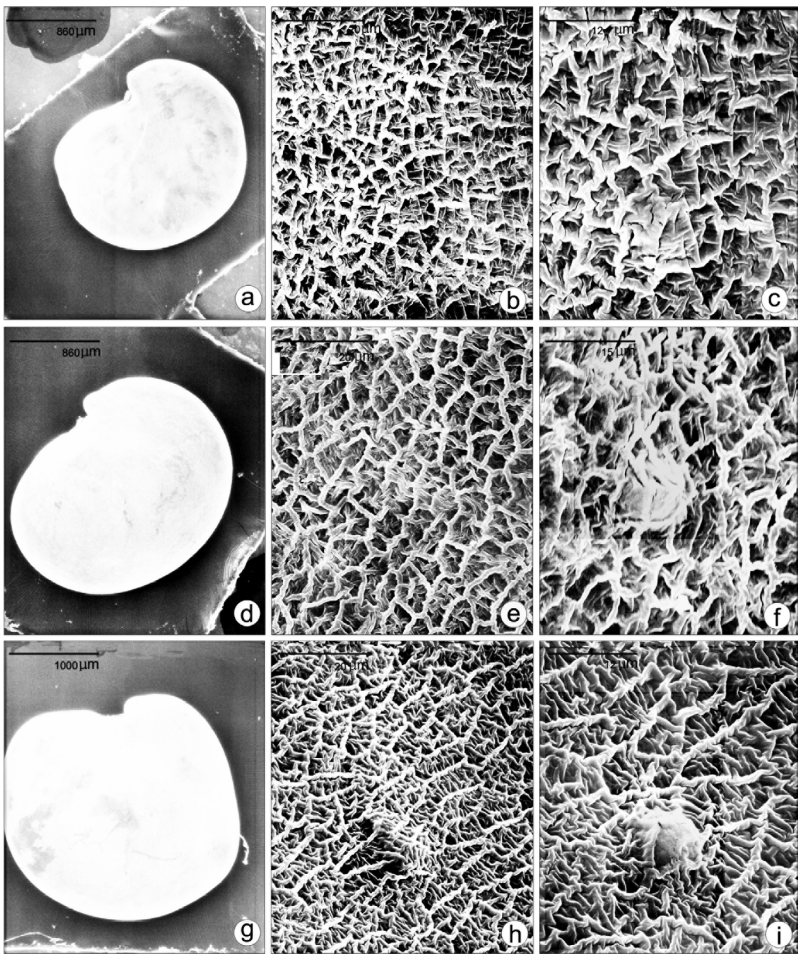

Fig. 2. Seed coat sculpture characteristics of the *Hedysarum gmelinii* complex under SEM. — **a**–**c**: *H. gmelinii*. — **d**–**f**: *H. dahuricum*. — **g**–**i**: *H. setigerum*.

the ecological conditions: dwarf plants usually occurred at higher and drier habitats. As shown above, *H. setigerum* of the *H. gmelinii* complex in its entire range is distributed at much higher elevations. Some other distinguishing characteristics, such as those of leaflets and petals as given in former studies (Fedchenko 1948, Xu 1998) were flexible or even contradictory. When the first author of this paper examined the types of the three *Gmelinii*-group taxa at LE, she failed to find morphological differences that would support their separation.

The seed coat characteristics were investigated for further evidence in reevaluation of the taxonomic status of the three taxa. Little information was found in the literature on *Hedysarum* seed morphology. However, it has been shown to provide valuable characters for systematic study in the Fabaceae (Gunn 1981) and many other plant families (Esau 1953, Mohana 1974, Corner 1976, Barthlott 1981, 1984, Shetler 1986, Takhtajan 1991, Zhang *et al*. 2005). In addition to gross morphology of the seeds, the outer seed coat sculpture could be quite variable and of systematic importance in many legume groups (Sa *et al*. 2000, Zhu 2003).

Therefore, the seeds of *H. gmelinii*, *H. dahuricum*, *H. setigerum*, as well as of *H. brachypterum* and *H. dasycarpum* of sect. *Multicaulia*, and of *H. splendens* and *H. jaxartucirdes* of sect. *Subacaulia* were examined. The seeds of the three study species were reniform and the hilum region was grooved; the seed coat cells were all irregular, relatively small, the texture was reticulate, the walls sinuous and thickened, and the luminae more or less isodiametric. The seed

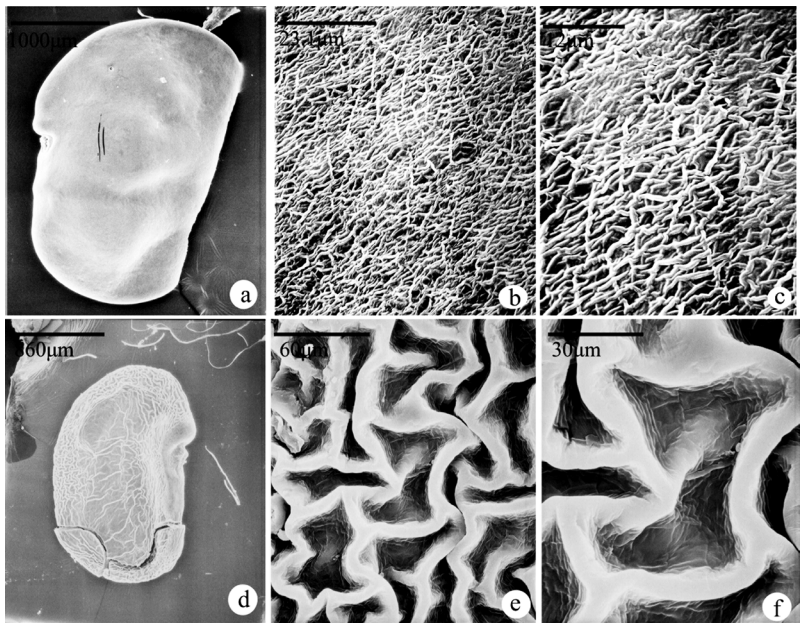

Fig. 3. Seed coat sculpture characteristics under SEM. — **a–c**: *Hedysarum brachypterum*. — **d–f**: *H. dasycarpum*.

coat sculptures of the three species appeared barely distinct in anything other than cell sizes (Fig. 2). However, the seed coat sculpture was different among the species (*see* Table 2; Tang *et al*. 2007).

In sect. *Multicaulia*, *H. brachypterum* was significantly different from *H. gmelinii*, even if the two species are very similar in morphology, and just distinguished by the length of wings. The seeds of *H. brachypterum* (Fig. 3a–c) are reniform to oblong and the seed coat cells are highly irregular, relatively small. The sculptures are reticulate, walls sinuous, thickened, luminae lengthened and apparently isodiametric. The seeds of *H. dasycarpum* (Fig. 3d–f) are reniform and the seed coat cells are highly irregular, large. The sculptures are reticulate, walls sinuous, extremely thickened, and luminae highly irregular.

In sect. *Subacaulia*, *H. splendens* and *H. jaxartucirdes* are also clearly different from *H. setigerum*. The seeds of *H. splendens* (Fig. 4d–f) are

Table 2. Seed coat characteristics in *Hedysarum gmelinii* group and some other species in *Hedysarum*.

Species	Gross seed coat appearance	Cell shape	Cell wall sculpturing characteristics
H. brachypterum	reticulate	highly irregular, relatively small	sinuous, thickened, luminas lengthened and apparently isodiametric
H. dahuricum	reticulate	irregular, relatively small	sinuous, thickened, luminas more or less isodiametric
H. dasycarpum	reticulate	highly irregular, large	sinuous, extremely thickened, luminas highly irregular
H. gmelinii	reticulate	irregular, relatively small	sinuous, thickened, luminas more or less isodiametric
H. jaxartucirdes	cerebelloid	extremely small, highly irregular	sinuate, thickened, luminas highly irregular
H. setigerum	reticulate	irregular, relatively small	sinuous, thickened, luminas more or less isodiametric
H. splendens	almost reticulate	highly irregular, relatively small	sinuous, thickened, luminas small, lengthened and apparently not isodiametric

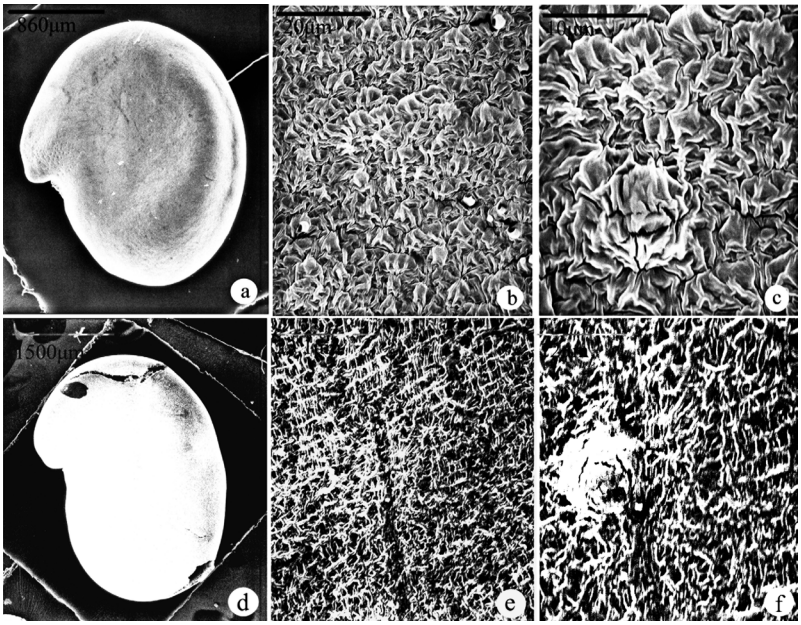

Fig. 4. Seed coat sculpture characteristics under SEM. — **a–c**: *Hedysarum jaxartucirdes*. — **d–f**: *H. splendens*.

reniform, the seed coat is relatively smooth, and the cells are highly irregular, relatively small. The seed coat cells are highly irregular, relatively small, the sculpture inconspicuously reticulate, walls sinuous, thickened, luminae small, lengthened and apparently not isodiametric. The seeds of *H. jaxartucirdes* (Fig. 4a–c) are also reniform, and the seed coat sculpture is mainly cerebelloid, extremely small, highly irregular, and the cell walls sinuate (Sa 2007).

It is not justified to recognize *H. dahuricum* and *H. setigerum* as distinct species, based on the petal color, short or absent above-ground stem (which are all different from *H. gmelinii*), but they should be treated as varieties under *H. gmelinii*. The revised taxonomy is below. The results also showed that the delimitation of sections *Multicaulia* and *Subacaulia* was unclear, and should be further studied.

Hedysarum gmelinii was described by Ledebour in 1812 based on material from Siberia; however, the type was not designated at that time. During a visit to LE, the first author examined *H. gmelinii* among other types, and found four sheets of specimens but none with a type designation. Of these, one sheet was recorded from Siberia without any other information, two sheets were only with collection numbers 82 and 84 respectively, and the fourth one was collected by Fischer in 1834, with two parts, numbered 21 and 22. As *H. gmelinii* was published in 1812 the fourth one cannot be the type. The second and the third sheets are without designation of collection sites. Therefore, the authors think that the first sheet should be the lectotype of *H. gmelinii*.

Hedysarum gmelinii Ledeb.

Mém. Acad. St. Pétersb. 5: 551. 1812. — LECTOTYPE (designated here): Russia. Siberia, *Anonymous s.n.* (LE!).

REPRESENTATIVE SPECIMENS EXAMINED. **China**. Nei Mongol: *L.R. Xu 2* (PE); *Biological Department 328* (PE); *Anonymous 4985* (WUK); *Yellow River Team 5616* (WUK). Hebei: *Y.W.Tsui 443* (PE); *Sin-Nun Lu 103* (PE). Shanxi/Shensi: *Shensi Team 471* (PE). Gansu: *Y.Y. Pai 144* (PE); *T.P. Wang 17331* (WUK). Xinjiang: *Xinjiang Expedition Team 176* (WUK). Ningxia: *Y.C. Hou 02386* (WUK); *Y.C. Hou 02247* (WUK); *Innermongolia-Ningxia Expd. Team 184*, *357*, *371*, *672* (HIMC); *Ma & Wu 57* (HIMC); *X.R. Shen 58* (HIMC); *Innermongolia Expd. Team 68* (HIMC); *W.S. Yang 325* (HIMC); *Innermongolia-Ningxia Expd. Team 1-68* (IMDC); *Anonymous 462* (FGC); *C.P. Wang 057* (FGC, NMAC); *Anonymous 771* (FGC); *Grassland Institute 15* (FGC); *Anonymous 192* (NMAC); *X.L. Yang 83119* (LZD); *Yunatov et al. 402* (LE); **Mongolia**. *Grubov et al. 518* (UBA); *Sanqir et al. 1685* (UBA); *Yunatov 214*, *2851*, *2852*, *8336*, *8702*, *11477*, *12631*, *12768*, *16919*, *18212* (LE); *Dashnyamaa et al. 221* (LE); *Grubov et al. 136* (LE); *Banzragch et al. 4739* (LE); *Grubov 5738* (LE); *Grubov et al. 1317*, *1349*, *1668* (LE); *Dashnyam et al. 907* (LE); *Krasnikova et al. 1685* (LE). **Russia**. *Plennik et al. s.n.* (ALTB); *Shmakov et al. s.n.*

(ALTB); *Namzalov et al. s.n.* (ALTB); *Kamelin et al. 2306* (ALTB); *Koroleva et al. s.n.* (NS); *Krasnoborov et al. s.n.* (NS); *Angyrban s.n.* (NS); *Pavlova et al. s. n.* (NS); *Pavlova 8785*, *8796* (NS); *Ershova et al. 5512* (NS); *Kuminova et al. s.n.* (NS); *Likova et al. 595*, *596*, *597* (NS); *Neifeld et al. s.n.* (NS); *Sobolevskaya et al. s.n.* (NS); *Rubtzova et al. s.n.* (NS); *Zvereva et al. s.n.* (NS); *Alexeyeva et al. s.n.* (NS); *Maskayev et al. s.n.* (NS); *Koroleva et al. s.n.* (NS); *Sedelnikov et al. s.n.* (NS); *Artemova et al. s.n.* (NS); *Krasnikova s.n.* (NS); *Opustynennaya et al. s.n.* (NS); *Listova et al. s.n.* (NS); *Penkovskaya et al. s.n.* (NS); *Albitskaya et al. s.n.* (NS); *Lapshina et al. s.n.* (NS); *Ronginskaya al. s.n.* (NS); *Morgacheva s.n.* (NS); *Pshenichnaya et al. s.n.* (NS); *Lestunova et al. s.n.* (NS); *Kuminova et al. s.n.* (NS); *Smirnow s.n.* (NS); *Laschinskiy et al. s.n.* (NS); *Shaulo s.n.* (NS); *Danilov et al. s.n.* (NS); *Shaulo et al. s.n.* (NS); Kazakhstan: *Isachenko et al. 2611* (LE); *Rubtzova 6046* (LE); *Isachenko 6048* (LE); *Isachenko et al. 2543*, *2579*, *3125*, *3175*, *3208* (LE).

Key to the varieties of *Hedysarum gmelinii*

1. Without distinct above-ground stem or stem clearly shortened; growing on sandy steppe at 1800–2350 m .... *H. gmelinii* var. *setigerum*
1. Usually with distinct above-ground stem 2
2. Flowers purple, sometimes with yellow patches; growing at alpine meadows or stony steppes at 800–2400 m .... *H. gmelinii* var. *gmelinii*
2. Flowers yellow, rarely with purple patches; growing at stony steppes at 600–700 m .. *H. gmelinii* var. *dahuricum*

Hedysarum gmelinii var. ***dahuricum*** (Turcz. *ex* B. Fedtsch.) R. Sa, *comb. nova*

H. dahuricum Turcz. *ex* B. Fedtsch., Fl. URSS 13: 290. 1948. — Type: Russia. Onon-Barsy, 1891 *Turczaninow s.n.* (holotype LE!).

Representative specimens examined. **China**. Heilongjiang: *G. Sat 234* (PE). Nei Mongol: *L.R. Xu 095* (PE); *T.N. Liou 8353* (PE); *C. Wang et al. 863* (PE); *C. Wang 863* (WUK); *Y.Z. Zhao 353* (HIMC). **Mongolia**. *Gubanov 1077* (LE); *Potanin s.n.* (LE); *Lomonosova s.n.* (NS); *Alarichev s.n.* (NS); *Lomonosova et al. s.n.* (NS); *Malzew s.n.* (NS); *Dashnyam s.n.* (LE); *Taschekova et al. 478*, *526* (LE); *Yunatov 1474*, *11907* (LE).

Hedysarum gmelinii var. ***setigerum*** (Turcz. *ex* Fisch. & Mey.) R. Sa, *comb. nova*

Representative specimens examined. **Russia**. *Kamelin et al. 1538*, *1585*, *2104*, *s.n.* (ALTB); *Shmakov s.n.* (ALTB); *Skvortsova s.n.* (NS); *Zvereva et al. s.n.* (NS); *Sobolevskaya s.n.* (NS); *Krasnoborov 1991*, *s.n.* (NS); *Tyulina et al. s.n.* (NS). **Mongolia**. *Anonymous 5392* (UBA); *Knarr 443* (UBA); *Grubov et al. 697* (UBA); *Malyshev 135* (LE); *Potanin s.n.* (LE); *Momkiy s.n.* (LE); *Dashnyam s.n.* (LE); *Dadochkin 807* (LE).

Summary

The *Hedysarum gmelinii* group (*H. gmelinii*, *H. dahuricum*, *H. setigerum*) was analyzed and it was found that separation of the taxa at species level was not supported by thorough comparative studies including flower color and color pattern, stem growth, and seed coat sculpture analyses. Authors concluded that the differences in *H. setigerum* and *H. dahuricum* are most likely the result of the interaction of environment on the same genetic constitution (genotype), and these taxa should indeed be considered conspecific and treated as varieties of *H. gmelinii*. During the studies authors also clearly saw that ecological factors much influence the appearance and variability of *Hedysarum*, thus the distinctive characters in their morphology were mostly a consequence of the environment, such as climate and soil, under which the species occur.

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