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
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 Hjiang-chian (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, Chrtkova 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.

<table>
<thead>
<tr>
<th>Species</th>
<th>Fedchenko’s (1902) system</th>
<th>Choi et al.’s (2003) system</th>
<th>Vouchers</th>
</tr>
</thead>
<tbody>
<tr>
<td>H. brachypterum</td>
<td>Sect. Multicaulia</td>
<td>Sect. Multicaulia</td>
<td>YW Tsui s.n., 8 Aug. 1949; Zhangbei County, Hebei Province (PE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Subsect. Multicaulia</td>
<td></td>
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<tr>
<td>H. dahuricum</td>
<td>Sect. Multicaulia</td>
<td>Sect. Multicaulia</td>
<td>Sino-Germany Team 8353; 21 Aug. 1956; Haila’er City, Inner Mongolia (PE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Subsect. Multicaulia</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Subsect. Multicaulia</td>
<td></td>
</tr>
<tr>
<td>H. gmelinii</td>
<td>Sect. Multicaulia</td>
<td>Sect. Multicaulia</td>
<td>Shanshi Team 471; 8 Aug. 1953; Shouzhou City, Shaansi Province (PE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Subsect. Multicaulia</td>
<td></td>
</tr>
<tr>
<td>H. jaxartucirides</td>
<td>Sect. Subacaulia</td>
<td>Sect. Multicaulia</td>
<td>R.C. Ching 1605; 8 Aug. 1956; Qinghe County, Xinjiang Province (PE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Subsect. Subacaulia</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Subsect. Subacaula</td>
<td></td>
</tr>
<tr>
<td>H. splendens</td>
<td>Sect. Subacaulia</td>
<td>Sect. Multicaulia</td>
<td>V.I. Vereshatin s.n.; 7 Jun. 1999; Semipalatinskaja Obl. (NS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Subsect. Subacaula</td>
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</table>
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. *Subacaulla* 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 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).

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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>
<thead>
<tr>
<th>Species</th>
<th>Gross seed coat appearance</th>
<th>Cell shape</th>
<th>Cell wall sculpturing characteristics</th>
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</thead>
<tbody>
<tr>
<td>H. brachypterum</td>
<td>reticulate</td>
<td>highly irregular, relatively small</td>
<td>sinuous, thickened, luminae lengthened and apparently isodiametric</td>
</tr>
<tr>
<td>H. dahuricum</td>
<td>reticulate</td>
<td>irregular</td>
<td>sinuous, thickened, luminae more or less isodiametric</td>
</tr>
<tr>
<td>H. dasycarpum</td>
<td>reticulate</td>
<td>highly irregular, large</td>
<td>sinuous, extremely thickened, luminae highly irregular</td>
</tr>
<tr>
<td>H. gmelinii</td>
<td>reticulate</td>
<td>irregular</td>
<td>sinuous, thickened, luminae more or less isodiametric</td>
</tr>
<tr>
<td>H. jaxartucirdes</td>
<td>cerebelloid</td>
<td>extremely small, highly irregular</td>
<td>sinuate, thickened, luminae highly irregular</td>
</tr>
<tr>
<td>H. setigerum</td>
<td>reticulate</td>
<td>irregular</td>
<td>sinuous, thickened, luminae more or less isodiametric</td>
</tr>
<tr>
<td>H. splendens</td>
<td>almost reticulate</td>
<td>highly irregular, relatively small</td>
<td>sinuous, thickened, luminae small, lengthened and apparently not isodiametric</td>
</tr>
</tbody>
</table>
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.


**REPRESENTATIVE SPECIMS 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); *Anonymous 462* (FGC); C.P. Wang 057 (FGC, NMAC); Innermongolia-Ningxia Expd. Team 1-68 (IMDC); *Anonymous 426* (FGC); *C.R. 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); *Dashnaymaa et al. 221* (LE); *Grubov et al. 136* (LE); Banzragch et al. 4739 (LE); Grubov 5738 (LE); *Grubov et al. 1317, 1349, 1668* (LE); *Dashnayam et al. 907* (LE); Krasnikova et al. 1685 (LE). **Russia**. Plenik et al. s.n. (ALTB); Shmakov et al. s.n.
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. Hei-longjiang: 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. Gabanov 1077 (LE); Potanin s.n. (LE); Lomonosova s.n. (NS); Alarichev s.n. (NS); Lomonosova et al. s.n. (NS); Malzow s.n. (NS); Dashnyam s.n. (LE); Tschekova 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); Krasnoblory 1991, s.n. (NS); Tyulina et al. s.n. (NS). — Mongolia. Anonymous 5392 (UBA); Knarr 443 (UBA); Grubov et al. 697 (UBA); Malyshov 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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**References**


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