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A new section in *Malus* (Rosaceae) from China

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A new section in the genus *Malus* Miller (Rosaceae), sect. *Yunnanenses* (Rehd.) G. Z. Qian, is segregated from the sect. *Sorbomalus* Zabel *ex* Schneid. The new section differs from sect. *Sorbomalus* mainly by the leaves with more than five shallow lobes (or non-lobed), persistent calyx, five styles in flowers, and subglobose fruits with grit-cells and dots. Four species are placed in sect. *Yunnanenses*, all of them endemic in China: *M. honanensis* Rehd., *M. yunnanensis* (Franch.) Schneid., *M. ombrophila* Hand.-Mazz. and *M. prattii* (Heml.) Schneid.

Key words: *Malus*, Rosaceae, taxonomy

Introduction

Malus is mainly distributed in the northern temperate zone, China being one of the centers of diversity. Koehne (1893) divided the genus into sections *Calycomeles* Koehne (calyx deciduous) and *Gymnomeles* Koehne (calyx persistent). Since then, many authors have attempted to establish a natural infrageneric classification. Zabel (1903) divided *Malus* into sections *Eumalus* Zabel and *Sorbomalus* Zabel (without description), based on divided *vs*. undivided leaves. Most subsequent authors have followed Zabel's classification. For example, Schneider (1906a) described Zabel's two sections and added two new ones, *Eriolobus* (Seringe) Schneid. and *Docyniopsis* Schneid. (Schneider 1906b). Rehder (1920) created his own system based on Schneider's, adding sect. *Chloromeles* (Decaisne) Rehd., and established six subsections under the now five sections. Later (Rehder 1927) he changed "subsection" to "group" (1927), and finally transformed them into "series" (Rehder 1940). Most authors have now adopted Rehder's system, including Yu *et al*. (1956), Yu (1974), Langenfelds (1991) and Li (2001).

Rehder's system was of course not "perfect" and some taxa and names have been modified. "Sect. *Eumalus* Zabel *ex* Schneid.", which was divided into two series, must be recognized as sect. *Malus*. The two series, *Pumilae* (Rehd.) Rehd. (which should be ser. *Malus*) and ser. *Baccatae* (Rehd.) Rehd. differ from each other by the calyx persistence and fruit size. Fruits in ser. *Pumilae* were big and the calyx was persistent, while fruits in ser. *Baccatae* were much smaller and the calyx was deciduous.

Thinking of the differences between the two series in sect. *Malus*, Langenfelds (1991) amended Rehder's system, adopting the autonym

sect. *Malus*, and ascending the two series into sections. The sections were *Malus* with much bigger fruits and persistent calyx, and *Gymnomeles* Koehne with small fruits and deciduous calyx. A sectional status for these two groups was also supported by biochemical (Williams 1982) and molecular studies (Robinson *et al.* 2001, Liang *et al.* 2003).

In sect. *Sorbomalus* of Rehder's system, there were four series and ten species. Ser. *Sieboldianae* (Rehd.) Rehd. included *M. floribunda* Sieb., *M. zumi* (Matsum.) Rehd., *M. sargentii* Rehd. and *M. toringo* Sieb.; ser. *Florentinae* (Rehd.) Rehd. accommodated only *M. florentina* (Zucc.) Schneid.; ser. *Kansuenses* (Rehd.) Rehd. included *M. kansuensis* (Batal.) Schneid., *M. bhutanica* (W.W. Smith) J.B. Phipps (as *M. toringoides* (Rehd.) Hughes.), *M. fusca* (Raf.) Schneid. and *M. honanensis* Rehd.; ser. *Yunnanenses* (Rehd.) Rehd. included *M. yunnanensis* (Franch.) Schneid. (which was previously in genus *Eriolobus* and were transferred to *Malus* Sect. *Eriolobus* (Seringe) Schneid. by Schneider (1906b, 1912), and *M. prattii* (Hemsl.) Schneid. (Schneider 1906a) and *M. ombrophila* Hand.-Mazz. (Handel-Mazzetti 1926), which were previously in sect. *Eumalus*.

Although the leaves in ser. *Sieboldianae* were folded in buds (Jiang 1989 reported them as convolute or conduplicate-convolute) and often lobed, that series had more characters of ser. *Baccatae*, such as the morphology of flowers, inflorescences and fruits. Chemical and molecular evidence also supported that ser. *Sieboldianae* be recognized as sect. *Gymnomeles*. Terpo (1968) showed that ser. *Florentinae* should be transferred to another section due to the free top of fruit core, and this was also supported by the chemistry and molecular data. Thus, Rehder's sect. *Sorbomalus* comprised of two series: ser. *Yunnanenses* with a persistent calyx, bigger fruits with dots and grit-cells plus five styles, and ser. *Kansuenses* with a deciduous calyx, small fruits without or with very few grit-cells, plus two to three styles.

During our taxonomic studies we found that the situation in sect. *Sorbomalus* was very similar to that in sect. *Malus*, and the morphological differences in the former were even more obvious. Chemical and molecular data (*see* below) also pointed to the same direction. Thus, we propose to recognize ser. *Yunnanenses* as a section.

Taxonomic treatment

Malus Miller *sectio* ***Yunnanenses*** (Rehd.) G.Z. Qian, *stat. & comb. nov.*

Sect. *Sorbomalus* Zabel *ex* Schneid. subsect. *Yunnanenses* Rehd., J. Arn. Arb., 2: 48. 1920. — Sect. *Sorbomalus* Zabel *ex* Schneid. ser. *Yunnanenses* (Rehd.) Rehd., Man. Cult. Tree Shrub, ed. 2, 390. 1940, *syn. nov.*

Sect. *Eriolobus* (Seringe) Schneid. *in* Fedde, Rep. Sp. Nov. Reg. Veg. (3): 178–180. 1906, *p.p.*

Docyniopsis (Schneid.) Koidzumi, Act. Phytotax. Geobot. 3: 162. 1934, *p.p.*

Sect. *Calycomeles* Koehne subsect. *Eriomeles* F.D. Likhonos, Trudy. Prikl. Bot. Genet. Selek. 52(3): 25. 1974. *excl. M. formosana* Kawak. & Koidz.

Subgen. *Sorbomalus* (Zabel *ex* Schneid.) Robertson, Syst. Bot. 16(2): 389. 1991, *p.p.*

Folia ovata vel ovato-oblonga, margine leviter lobata vel serrata. Flores calycis persistentis, stylis 5, raro 3. Fructus globosus vel ovatus, 5–12 mm diam., 3–5 loculares, calicibus coronatis persistentis, maculosis et glareosis cellulosis.

TYPE: *Malus yunnanensis* (Franch.) Schneid.

Leaf blade ovate or elliptic-ovate, variously 5- or less-lobed, or unlobed; calyx persistent, styles 5, rarely 3; fruits globose or oval, 5–12 mm diam., 3–5-loculed, with coronary calyx persistent, dotted and with numerous grit-cells.

All species of this section are endemic in China, most of them being distributed in the SW part of China (Yunnan, Sichuan, Guizhou, Xizhang, Hunan and Hubei Provinces). However, only *M. honanensis* occurs also in the northern provinces of Henan, Gansu, Hebei, Shanxi and Shaanxi. There are four species in this section.

Malus yunnanensis (Franch.) Schneid. var. *yunnanensis*

in Fedde, Rep. Sp. Nov. Reg. Veg. (3): 179. 1906. — *Pyrus yunnanensis* Franch., Pl. Delav. 228. 1889. — *Eriolobus yunnanensis* (Franch.) Schneid., Ill. Handb. Laubh. 1: 727. 1906. — *Cormus yunnanensis* (Franch.) Koidzumi, Jour. Coll. Sci. Univ. Tokyo 34(2): 75. 1913. — *Docyniopsis yunnanensis* (Franch.)

Koidzumi, Act. Phytotax. Geobot. 3: 196. 1934. — LECTOTYPE (designated by Langenfelds 1991): China. Yunnan bor.-occid., inter fluvios Landsang-djiang *et* Lu-djiang, ca. 28°, 3200 m, 30.IX.1915 *Handel-Mazzetti 842* (Herbario Naturhistorisches Museum in Wien (Austria), syntype: *Delavey 1991* (photo PE!)

M. yunnanensis var. *veitchii* (Hort.) Rehd., J. Arn. Arb., 4: 115. 1923. — *Pyrus veitchii* Hort., Gard. Chron. Ser. 3, 52: 288. 1912. — TYPE: China. Hupeh, Fang Hsien, 1600–2300 m, 19.V.1907 *E. H. Wilson No*. 2994 (not seen).

DISTRIBUTION: China: Guizhou, Hubei, Hunan, Shaanxi, Sichuan, Yunnan, Xizang Autonomous Region.

Malus prattii (Hemsl.) Schneid.

Ill. Handb. Laubh. 1: 719. 1906. — *Pyrus prattii* Hemsl., Kew Bull. (1895): 16. 1895. — *Docyniopsis prattii* (Hemsl.) Koidzumi, Acta Phytotax. Geobot. 3: 196. 1934. — TYPE: China. Sichuan, Tachienlu, *Pratt, No*. 93 *et* 824 (photo PE!).

DISTRIBUTION: China: Guizhou, Guangdong, Sichuan,Yunnan.

Malus ombrophila Hand.-Mazz.

Sitzgsanz. Akad. Wiss. Wien, 63:1. 1926. — TYPE: China. Yunnan bor.-occ., Valley Tjiontson- lumba infra Tschamutong to Salwin, 2250–2650 m, 28.VI.1916 *Handel-Mazzetti* 9119 (photo PE!).

DISTRIBUTION: China: Guizhou, Sichuan, Yunnan, Xizang Autonomous Region.

Malus honanensis Rehd.

J. Arn. Arb. 2: 51. 1920. — *Sinomalus honanensis* (Rehd.) Koidzumi, Acta Phytotax. Geobot. 3: 196. 1934. — TYPE: China. Honan: Sung Hsien, Shi-tze-miao, 26.V.1919 *Joseph Hers 489* (holotype; syntype *Hers 573*, not seen).

DISTRIBUTION: China: Gansu, Hebei, Henan, Hubei, Hunan, Shaanxi, Shanxi, Sichuan.

Discussion

Ser. *Kansuenses* and Ser. *Yunnanenses* were previously placed in the same section. However, many morphological differences show they should be recognized as separate sections.

Morphology

Vernation types and lobation of leaves were presumably so important that Rehder (1920, 1940) applied them to distinguish sect. *Eumalus* and sect. *Sorbomalus*. Although many taxa in both of them are variable, there are clear differences between the two series.

The leaves of sect. *Sorbomalus* are variably lobed, but the lobations are different in the two series. In ser. *Yunnanenses* the leaves are often lobed with more than five lobes on each side or not lobed (as in *M. prattii* and *M. ombrophila*), and the veins are pinnate. In ser. *Kansuenses* the leaves usually have only 1–2 lobes on each side, and the veins are palmate.

Folgner (1897, cited in Jiang 1989) found that the young leaves of sect. *Malus* are convolute in buds, while in sect. *Sorbomalus* they are conduplicate. Rehder (1940) used this character in a key to the sections. However, Jiang (1989) reported five types named involute, convolute, involutoconvolute, conduplicatoconvolute and conduplicate. Though the vernation types vary in some taxa, only the conduplicate type is found in ser. *Yunnanenses*, while no species with this type was in ser. *Kansuenses*. Therefore, we think that vernation and lobation of leaves can be used to segregate these two series, though the differences are not always very stable.

Calyx persistence is also very important in the classification of *Malus*. Koehne (1893) used it as the main character to separate sect. *Calycomeles* and sect. *Gymnomeles*. Persistent and deciduous calyces are found only in *M. sikkimensis* and *M. micromalus* (a cultivated hybrid species). So, this character is more stable than those in leaves, and should be used to distinguish sections instead of series. We support the treatment of Langenfelds (1991) to ascend ser. *Baccatae* to sect. *Gymnomeles*. Jiang (1996) and Li (2000) also agree with this opinion although they used the synonymous name sect. *Baccatus* N.G. Jiang.

As in sect. *Malus*, the most important differences between the two series in sect. *Sorbomalus* are the calyx persistence, the size of fruits, and the grit-cells. The fruits in ser. *Yunnanenses* have many dots and grit-cells, and persistent calyces, while the fruits in ser. *Kansuenses* have no or

very few dots and grit-cells, deciduous calyces, and the fruits are also smaller than those in ser. *Yunnanenses*.

So the two series in sect. *Sorbomalus* can be clearly distinguished morphologically. Below are the main morphological differences between the two sections.

Sect. *Sorbomalus*: Leaves 3–5-lobed, usually to a depth approaching one half of either side of the main vein, sometimes unlobed; veins pinnately nerved, with a couple of much thicker and longer veins at the base of leaves; calyx deciduous, styles 3, rarely 5, glabrous, rarely villous at base; fruits ellipsoid or obloid, without dots and grit-cells. The fruits in sect. *Sorbomalus* resemble those in sect. *Gymnomeles* rather than in sect. *Yunnanenses*.

Sect. *Yunnanenses*: Leaves usually 5- or less-lobed, sometimes unlobed; veins pinnately nerved, the basal vein not much bigger than the second one; calyx persistent, styles 5, rarely 3, glabrous, rarely villous at base; fruits globose or ovoid, dotted and with numerous grit-cells.

Biochemistry

According to Williams (1982, as ser. *Kansuenses*), sect. *Sorbomalus* has T (toringin, or chrysin 5-glucoside) and F (*dibenzoylmethane glucoside*), but lacks Q (quercetin 4´-glucoside), while sect. *Yunnanenses* is devoid of any distinctive phenolics of flavonoids. Sect. *Gymnomeles* has Q and N (naringenin 4´-glucoside), while sect. *Malus* also lacks any distinctive phenolics of flavonoids. Thus the presence/absence of flavonoids also support separation of sect. *Gymnomeles* from sect. *Malus* and sect. *Yunnanenses* from sect. *Sorbomalus*.

Molecular evidence

Liang *et al*. (2003) studied AFLPs of 23 wild species of genus *Malus* and got two similar dendrograms, one with UPGMA (Liang *et al*. 2003, and Fig. 1), the other one with WPGMA. We reproduce one of his two figures here and marked the sections in it. In both dendrograms, ser. *Yunnanenses* was separated from ser. *Kansuenses*. Species of ser. *Yunnanenses* clustered in one clade, while species of ser. *Kansuenses* formed two clades. Of the latter species *M. bhutanica*, *M. xiaojinensis*, *M. daochengensis*, and *M. maerkangensis* formed one clade. The last three species were shown to be hybrids between *M. bhutanica* and *M. kansuensis* and so difficult to distinguish that they should be combined. *Malus bhutanica* was a very special species, it was very similar to *M. transitoria* in the morphology, but the chemical data showed that it belonged in sect. *Gymnomeles*. More needs to be done to ascertain the systematic status of *M. bhutanica*. According to the morphological analyses, *M. sieboldii* grouped in sect. *Gymnomeles* and *M. florentina* grouped in sect. *Eriolobus*. The AFLP results clearly support the separation of sect. *Yunnanenses* from sect. *Sorbomalus*.

Unlike in the AFLP analyses, ser. *Yunnanenses* and ser. *Kansuenses* did not form clear monophyletic clades in the ITS sequence analyses (Robinson *et al*. 2001: fig. 3A). Their clades 1A and 1B corresponded to sect. *Malus* and sect. *Gymnomeles*. Species of sect. *Sorbomalus* assembled in clades 1C and 2. *Malus transitoria* and *M. bhutanica* (as *M. toringoides*) formed a sister group close to sect. *Gymnomeles*. Two accessions of *M. fusca* grouped with *M. kansuensis* and ser. *Yunnanenses*, but a third one was nested within sect. *Malus*. However, the latter accession was from a garden and the identification is not certain, so that result might be erroneous. The ITS analysis results were somewhat unconvincing due to the weak bootstrap support. The results may also have been disturbed due to ancient hybridization, lineage sorting, or other reasons.

The characteristics of the two sections are clearly different, and the only way to keep uniformity in the sections is to separate them. But which one should be separated as a new section?

Neither Zabel (1903) nor Schneider (1906) indicated the type of sect. *Sorbomalus*. *Malus florentina* (Zucc.) Schneid. was the first species mentioned by Schneider (1906a), but it is different from the other species in the section and it belongs in sect. *Eriolobus* (Terpo 1968). *Malus zumi* was the second species that could be the type of sect. *Sorbomalus* but, as we will discuss in a forthcoming paper, it actually belongs in ser. *Sieboldianae*. Langenfelds (1991) selected *M.*

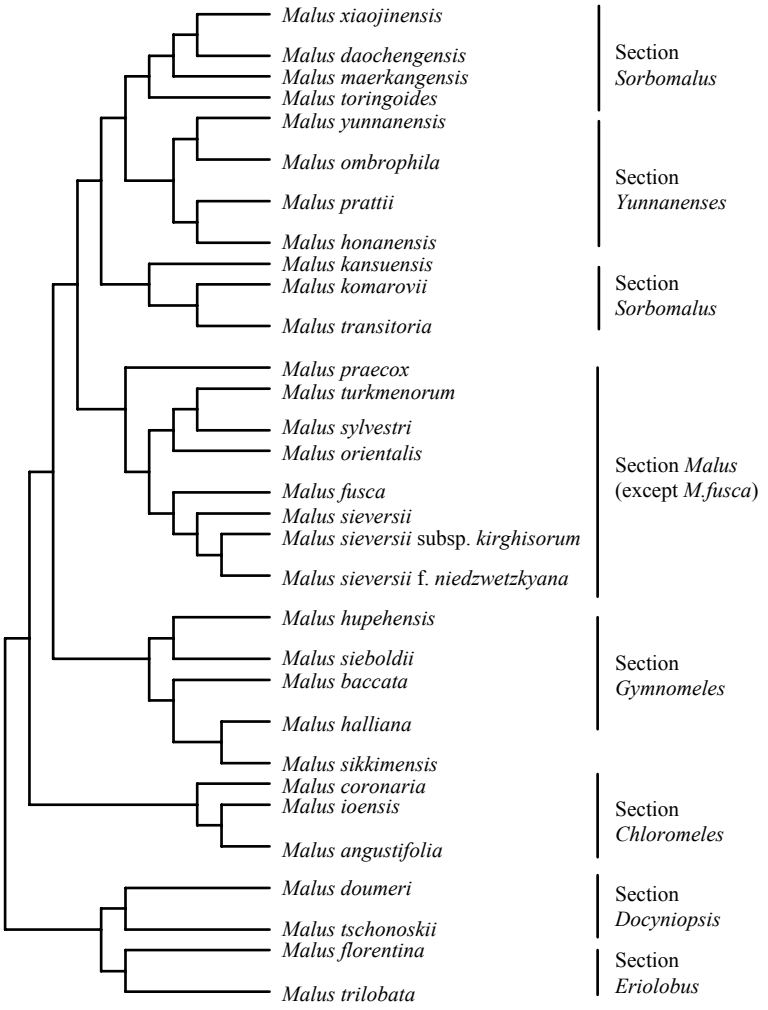

Fig. 1. UPGMA dendrogram of 31 wild species or inner species taxa, based on the data of primer combinations: E-AAC, M-CAC, E-ACG, M-CAG, E-ACT, M-CAG. (Modified from Liang *et al.* 2003: fig. 1, the section names were added by the authors).

kansuensis as the type of this section. Thus, we separate ser. *Yunnanenses* and recognize it as a new section.

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