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Helicodraba, a new genus of *Arabideae* (Brassicaceae) endemic to Morocco

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Summary. A new generic name, *Helicodraba*, based on *Draba* sect. *Helicodraba*, is validated to accommodate one to two NW African (Moroccan part of Atlas Mts.) species morphologically and molecularly sharply deviating from the rest of *Draba*. Relevant specific and subspecific combinations are also published, lectotype designations are made and commented where needed. Besides, two combinations are validated in *Erophila*.

Helicodraba – новый род трибы *Arabideae* (Brassicaceae), эндемичный для Марокко

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Аннотация. В сообщении обнаружится новое родовое название *Helicodraba*, основанное на *Draba* sect. *Helicodraba*. Новый род включает от одного до двух видов, произрастающих на северо-западе Африки (марокканская часть Атласских гор) и морфологически сильно уклоняющихся от остальных представителей рода *Draba*, что соответствует и молекулярно-филогенетическим данным. Приводятся соответствующие комбинации видового и подвидового ранга, выбор лектотипов и необходимые пояснения. Дополнительно в род *Erophila* переводится два вида, недавно описанные в составе *Draba*.

Introduction

Among more than 400 species (Al-Shehbaz, 2018; 427 – authors' count) of the largest Brassicaceae (Cruciferae) genus *Draba* L., only one, *D. hederifolia* Coss. (or two, if subsp. *cossoniana* Maire is accepted as *D. cossonii* O. E. Schulz), endemic to High and Middle Atlas Mts., is peculiar for basal leaves with suborbicular-reniform, lobate and cordate at base blade sharply differentiated from much longer petiole. This feature provides superficial resemblance of *D. hederifolia* s. l. with members of *Graellsia* Boiss., a small (nine spp.; Esmailbegi et al., 2017) genus of SW Asian distribution, which prompted Hyam and Jury (1990) transferring the Moroccan species to the latter genus. Subsequent phylogenetic studies (Jordon-Thaden et al., 2010; Karl, Koch, 2013) demonstrated natural position of *D. hederifolia* in *Arabideae* DC., a tribe not closely related to *Thlaspidaceae* DC., where *Graellsia* belongs to (Al-Shehbaz, 2012), thus proving purely convergent character of the mentioned habitual similarity and fully supporting earlier conclusion of Poulter (1956) treated the two entities unrelated.

Generic placement of *D. hederifolia* s. l. was controversial from the very beginning: yet with the first mention of the species, then undescribed, Cosson (1875) questioned it as "*Draba ? hederifolia*". The problem was discussed by Jordon-Thaden et al. (2010) based on their first in-depth genus-wide phylogenetic study of *Draba*. These authors found its position in relation to the rest of the genus somewhat ambiguous, grouping, together with several New World *Draba* segregates nowadays recognized as separate genera *Abdra* Greene, *Athysanus* Greene and *Tomostima* Raf., outside the core *Draba* clade in ITS-based phylogeny or being, along with *D. verna* L. [also found outside core *Draba* in nr-based trees], earliest-deriving clades from the bulk of the genus in *trnL-F* phylogeny, as also found by Karl and Koch (2013). Though with an admission of possible correction, a conservative approach was applied, viz. keeping both *D. hederifolia* and *D. verna* in *Draba*, implying paraphyly of the genus, at least based on nuclear phylogeny, further supported by unpublished own data. In the most recent family-wide phylogenetic analysis focusing on accepted genera and using a set of 1,000 genes, both taxa, *D. verna* and *D. hederifolia*, were missing (Hendriks et al., 2023), whilst other above-mentioned segregates closely related to *Draba* (namely *Tomostima*, *Abdra* and *Athysanus*) were included and grouped as monophyletic clade sister to *Draba*.

In summary, the inconsistent or uncertain phylogenetic position of *D. verna* and *D. hederifolia* with respect to *Draba* and the other generic segregates remained during the past years, and just recently a new phylogenetic approach has been introduced to unravel deep evolutionary reticulation and hybridization events (Walden et al., 2024). The approach relies on the reconstruction of a robust diploid backbone phylogeny based on more than 1,000 genes from the nuclear genome and using the individual paralogous genes of taxa under consideration to map their putative reticulate origin onto the phylogenetic backbone. The practical and theoretical concepts have been introduced exemplifying more than 450 accessions from *Arabideae*, which includes the herein discussed focal taxa. We used relevant results from this study to explore the evolutionary history of *D. verna* and *D. hederifolia* and present new insights into their deep reticulate history. Here we introduce a first proof-of-concept contribution, that the Paralogous PhyloGenomics (PPG) (Walden et al., 2024) can provide strong arguments for convincing taxonomic treatments in otherwise taxonomically challenging clades. *Arabideae* is a tribe with 63 % polyploid species, compared to approximately 43 % across the entire Brassicaceae (Hohmann et al., 2015). Although there is a robust understanding of relationships among major clades within the tribe (Karl, Koch, 2013), a series of contributions (Koch et al., 2006, 2010, 2012, 2017; Jordon-Thaden et al., 2010; Karl et al., 2012; Karl, Koch, 2013, 2014) highlighted substantial hybridization, reticulation, and introgression on various spatiotemporal scales, from closely related species to rather distant lineages of *Arabideae*.

Here, we argue for an alternative treatment removing the above-mentioned paraphyly of *Draba* which means recognition of both *D. hederifolia* and *D. verna* as members of separate genera. For the latter, it means acceptance of *Erophila* DC., a genus long and widely recognized in botanical literature and differing from *Draba* by divided petals. In contrast, *D. hederifolia* s. l. was never treated in a genus other than *Draba* or *Graellsia*, and erection of a new one is required under the suggested concept. For this, a combination based on relevant infrageneric taxon of a sectional rank validated by Schulz (1927) to accommodate the species in question, is most suitable. With the proposed exclusion of *Helicodraba* and *Erophila*, morphological delimitation of *Draba* is altered in a way that divided petals and 'Graellsia-like' leaves are eliminated, leaving the rest of its characters unchanged.

Materials and methods

The study is based on treatment of *Draba hederifolia* s. l. collections of the herbaria mentioned below, of which specimens in B, BM, BP, BR, C, FI, G, K, LD, LE, P, W, WU, and Z were studied physically and others via the online platforms Global Plants (2024) and RECOLNAT (2024). “International Code of Nomenclature...” (Turland et al., 2018) was used as a guide in nomenclatural actions and considerations.

Phylogenetic inference and conclusions are based on the results presented by Walden et al. (2024) and details can be found therein.

Results

Phylogenetic placement

Among the studied clades and taxa from the tribe *Arabideae* ($n = 387$ accepted taxa [species and a few subspecies] following BrassiBase; Kiefer et al., 2014), a reliable diploid backbone phylogeny has been presented based on 994 nuclear encoded genes (Walden et al., 2024). Using this phylogenetic framework for paralogue placement of taxa identified or known as polyploids (such as *Draba verna* and *D. hederifolia*; Kiefer et al., 2014), the analyses resulted in 43 clusters of species with contrasting evolutionary history. Many of them indicate ancient hybridization, introgression and reticulation.

Draba hederifolia belongs to cluster no. 24 together with *Tomostima*, *Abdra* and *Athysanus*. Its origin is a deep reticulate event between progenitors of diploid *Draba* and a contact with some other *Arabideae* representatives (ancestors of *Arabis aucheri* Boiss., *Aubrieta* Adans. or the *Arabis alpina* L. – *A. auriculata* Lam. clade). The origin of this clade of taxa (*Tomostima*, *Abdra*, *Athysanus* and *D. hederifolia*) is therefore 7–10 my ago [for divergence estimates refer to Karl and Koch (2013) and Huang et al. (2020)].

Erophila stands alone and is assigned to cluster no. 23 with strong reticulate affinities to ancestors of *A. aucheri* and the diploid stem group of *Draba*. The origin of *Erophila* is younger than that of *D. hederifolia*, and it is roughly estimated as ca. 5–7 my ago.

In summary, both taxa are of an old reticulate/hybrid origin and show strong but differing affinities to the progenitors of present-day *Draba*. These results favour a distinct generic treatment outside *Draba*.

Taxonomy

Helicodraba (O. E. Schulz) D. A. German et M. Koch, **gen. nov.** \equiv *Draba* sect. *Helicodraba* O. E. Schulz, 1927, in Engler, Pflanzenreich IV, 105 (Heft 89): 145.

Lectotype (designated here): *H. hederifolia*

The genus includes one to two rocky species confined to High and Middle Atlas Mountains (Morocco, NW Africa).

Helicodraba hederifolia (Coss.) D. A. German et M. Koch, **comb. nov.** \equiv *Draba hederifolia* Coss., 1880, Bull. Soc. Bot. France 27: 69. \equiv *Graellsia hederifolia* (Coss.) R. D. Hyam et Jury, 1990, Bot. J. Linn. Soc. 102(1): 21.

Original provenance indication: “In fissuris rupium montium imperii Maroccani interioris: Djebel Rat [Ghat] in ditone Ait Bou-Oulli provinciae Demnat, Djebel Ouensa ad austro-occidentem urbis Maroc (mulio Ibrahim)” (Cosson, 1880).

Lectotype (Hyam, Jury, 1990: 21 and designated here): “In fissuris rupium cacuminis montis Djebel Ouensa, ad austro-occidentem urbis Maroc, Maroc. Coll. Ibrahim 20 Junio 1875” [Plantae Atlanticae selectae exsicc. № 108] (LE 01079248; iso – ANG 032385; AUT 010937; B 10 0154840; B [s. n.]; FI (3 \times); G 00422881; G 00422882; K 000230448; LE 01079250; LE 01079251; LY 0103827; LY 0103829; LY 0683422; MPU 009598; MPU 567999; MPU 568000; P 05356335; P 05356366; P 05356368; P 05356376; P 05426074; VTA 062717; VTA 062224; VTA 062227; W 1889-26685; W [s. n.]).

Notes.

1. The protologue includes two localities, the first of which refers to the next taxon. In their type designation, Hyam and Jury (l. c.) mentioned Djebel Ghat instead of Djebel Ouensa, but the date (20 VI 1875) clearly belongs to the latter locality which is correctly given in citation of specimens examined. So, this inaccuracy should be treated as an error to be corrected not preventing designation of the part of relevant gathering kept in LE as type (correctable to lectotype under Art. 7.11 of ICN (Turland et al., 2018)). Since there are three duplicates of this collection mounted on two sheets in LE (https://herbariumle.ru/?t=occ&id=19029&rid=image_0047934; https://herbariumle.ru/?t=occ&id=19141&rid=image_0048046), a second-step lectotype is chosen here.

2. Remaining original material includes collections of 1873 by Ibrahim from the same locality (G, K, LE, LY, P, VTA) and specimens of plants cultivat-

ed in late 1870ths from seeds collected by him (P, VTA).

3. A specimen in BP (№ 201513) as if collected by Ibrahim in Djebel Ouensa on 20 June 1875, is mislabeled as it belongs to the next taxon and most likely represents original material of it.

Helicodraba hederifolia subsp. *cossoniana* (Maire) M. Koch, **comb. nov.** ≡ *Helicodraba cossonii* (O. E. Schulz) D. A. German, **comb. nov.** ≡ *Draba cossonii* O. E. Schulz, 1927, in Engler, Pflanzenreich IV, 105 (Heft 89): 147. ≡ *Draba hederifolia* subsp. *cossoniana* Maire, 1928, Bull. Soc. Hist. Nat. Afrique N. 19: 31. ≡ *Draba hederifolia* subsp. *cossonii* (O. E. Schulz) Maire, 1967, in Quézel & Lechevalier, Fl. Afrique N. 13: 278, **comb. illeg.** ≡ *Graellsia hederifolia* subsp. *cossonii* (O. E. Schulz) R. D. Hyam et Jury, 1990, Bot. J. Linn. Soc. 102(1): 21, as '(Schulz) Maire', **comb. illeg.**

Original provenance indication: "Südwestliche Mediterranprovinz. Marokko: Provinz Demnat, Djebel Ghat im Distrikt Aït Bou-Oulli (Ibrahim 1879 – am 5. August fruchtend, 1882 – am 28. Juli fruchtend)" (Schulz, 1927).

Lectotype (designated here): "Dj. Rat [Ghat]. Province de Demnat, Maroc. Ibrahim, 5 Août 1879" (B 10 0154839; iso – BM 013393288; BM 013393292; K 000230713; LE 01079252; MPU 567998; MPU 568001; MPU 568002; P 05356341; P 05356370; VTA 062226).

Notes.

1. The specimen from the less abundant collection from which an analytic drawing accompanying the protologue was made, is chosen as the lectotype in accordance with the ICN Recommendation 9A.3. (Turland et al., 2018).

2. Remaining original material is represented by syntypes: ANG 010779; AUT 010926; AUT 010987; B [s. n.]; BM 013393290; BM 013393291; BR 000006993177; BR 000006993504; C (2×); FI (6×); CLF 309885; G 00422868; G 00422889; G 00422870;

GAP 025985; K 000230712; LD 88/20-0562; LE 01039442; LY 0683423; MARS 15124; MARS 61185; MPU 008587; MPU 043199; MPU 567991; MPU 567993; MPU 567995; MPU 567996; MPU 568004; MPU 568006; P 05356330; P 05356331; P 05356333; P 05356372; P 05356377; P 05356379; P 05426072; SLA 050164; VIL 008372; VTA 053742; VTA 062776; WU; Z 000172756; Z 000172758. Among them, MPU043199, VTA 053742 and VTA 062776 are mixed with Ibrahim's collection of 27 June 1881 that was not known to Schulz and does not belong to the original material of *D. cossonii*.

3. Possibly MPU 567994 lacking the date and collector information also belongs to the original material of this taxon.

4. Since we have no agreement among us regarding the rank (species vs. subspecies) of this particular taxon, both viewpoints are presented here accepted just by one of us each. Hence, these are not alternative names that are invalid under current edition of ICN (Art. 36.3; Turland et al., 2018); approach used by Boiko et al. (2018) is applied here instead.

As for *Draba verna* and its affinity, nearly all species have relevant binomials in *Erophila*. Combinations for the remaining two recently published species (Bomble, 2020, 2021) are given here.

Erophila droserifolia (Bomble) D. A. German et M. Koch, **comb. nov.** ≡ *Draba droserifolia* Bomble, 2020, Veröff. Bochumer Bot. Ver. 12(5): 111; id., 2021, Jahrb. Bochum. Bot. Vereins 12: 38.

Erophila glauca (Bomble) D. A. German et M. Koch, **comb. nov.** ≡ *Draba glauca* Bomble, 2020, Veröff. Bochumer Bot. Ver. 12(5): 116; id., 2021, Jahrb. Bochum. Bot. Vereins 12: 43.

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