NOMENCLATURAL ADJUSTMENTS IN *EUTREMA, CERATOCNEMUM, RHAMPHOSPERMUM, AND SINAPIS* (BRASSICACEAE, CRUCIFERAE)

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Abstract. The following new combinations *Ceratocnemum aphanoneurum, C. ballii, Eutrema angustifolium, E. sulphureum, E. watsonii, Rhamphospermum labasii, R. nigrum,* and *R. pubescens* are proposed. As a result *Rhamphospermum* is resurrected, *Trachystoma* is reduced to synonymy of *Ceratocnemum*, and *Sinapis* becomes dispecific.

Keywords: Brassicaceae, *Ceratocnmum*, Cruciferae, *Eutrema*, *Rhamphospermum*, *Sinapis, Trachystoma*

The present study is the first in a series of forthcoming publications aimed to update the generic assignments of Brassicaceae species and infraspecific taxa to make these names available for the World Flora Online project in progress. The study is based on the critical re-examination of the boundaries of various genera in light of molecular data published so far. It deals with three species each of North African *Trachystoma* O.E. Schulz and Himalayan *Pegaeophyton* Hayek & Hand.-Mazz., and five species of Eurasian–North African *Sinapis* L.

Eutrema–Pegaeophyton

The latest revision of *Pegaeophyton* (Al-Shehbaz, 2000) recognized seven species restricted almost exclusively to the Himalayan region. Most recently, Hao et al. (2017) conducted extensive molecular phylogenetic studies on *Eutrema* R. Br., and their data strongly supported the transfer of three of them, including the generic type *P. scapiflorum* (Hook. & Thomson) C. Marq. & Airy Shaw, to *Eutrema* and a fourth species, *P. minutum* H. Hara, to *Aphragmus* Andrz. ex. DC. As currently recognized, *Eutrema* consists of 44 species centered primarily in the Himalayas and Central Asia. The diversity in plant size and fruit morphology surpasses that of any other genus in the family. For example, the fruit length can be as small as 1–2 mm (*E. nepalense* (Al-Shehbaz, Arai, & H. Ohba) Al-Shehbaz, G.Q. Hao & J. Quan Liu) to as long as 35 cm (*E. renifolium* (Boiss. & Hohen.) Al-Shehbaz, G.Q. Hao & J. Quan Liu); the fruit shape and compression can be terete, subquadrangular, latiseptate, or angustiseptate; the ovule number ranges from 2 to 96 per ovary; the seeds arrangement varies from uni- to biseriate; and the raceme ranges from fully bracteate to ebracteate.

The three remaining species of *Pegaeophyton* dealt with here were not included in any molecular studies because each is known only from the holotype sheet. However, their transfer to *Eutrema* hardly expands its generic limits, except for the development of a gamosepalous calyx in *E. watsonii*. Gamosepaly is rare in the family and has been reported in individual species of several unrelated genera that otherwise have a polysepalous calyx (Al-Shehbaz, 2001).

Eutrema angustiseptatum (Al-Shehbaz, T.Y. Cheo, L.L. Lu & G. Yang) Al-Shehbaz, *comb. nov.*
Basionym: *Pegaeophyton angustiseptatum* Al-Shehbaz, T.Y. Cheo, L.L. Lu & G. Yang in Al-Shehbaz, Edinburgh J. Bot. 57: 167. 2000.

Eutrema sulphureum (Al-Shehbaz) Al-Shehbaz, *comb. nov.*
Basionym: *Pegaeophyton sulphureum* Al-Shehbaz, Edinburgh J. Bot. 57: 169. 2000.

Eutrema watsonii (Al-Shehbaz) Al-Shehbaz, *comb. nov.*
Basionym: *Pegaeophyton watsonii* Al-Shehbaz, Edinburgh J. Bot. 57: 168. 2000.

Ceratocnemum–Trachystoma

The Moroccan *Ceratocnemum* Coss. & Balansa and *Trachystoma* O.E. Schulz belong to the Brassiceae, a tribe well defined morphologically by the presence of tribal-specific conduplicate cotyledons (longitudinally folded around the radicle) and/or heteroarthrocarpic (strongly segmented) fruit (Al-Shehbaz et al., 2006). However, generic delimitation in the tribe is problematic because molecular phylogenetic data (e.g., Arias and Pires, 2012, and references therein) clearly demonstrated that several genera (e.g., *Brassica* L., *Diplotaxis* DC., *Erucastrum* C. Presl, *Sinapis* L.) are polyphyletic. Genome triplication, hybridization, and reticulate evolution played a major role in the evolution and diversification of the Brassiceae (Lysak et al., 2005), and convergent evolution, even in the unique heteroarthrocarpic fruit (Hall et al., 2011), further complicates the traditional generic delimitation in the tribe. Therefore, a critical evaluation of morphology in light of molecular and genomic data would certainly lead to far more sensible taxonomy of genera than does morphology alone.

Ceratocnemum has been known for the past 177 years to be monospecific, whereas the later-published *Trachystoma* includes three species (see Al-Shehbaz, 2012). Both genera have similar leaf and flower morphology, heteroarthrocarpic fruit, and chromosome number of $2n = 16$. However, they differ in some details of fruit morphology: *Ceratocnemum*

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has oblong fruit with indehiscent, 1-seeded valvular (proximal) and distal segments, whereas *Trachystoma* has linear fruit with indehiscent or dehiscent, 1- or 3- to 15-seeded valvular segment and indehiscent 1- to 12-seeded distal segment.

Maire and Samuelsson (1939) indicated that *Ceratocnemum rapistroides* and *Trachystoma ballii* hybridize in nature, and they formally recognized their intergeneric nothogenus ×*Trachycnemum* Maire & Sam. (Type: *T.* ×*mirabile* Maire & Sam.). A detailed description of this intergeneric hybrid is given in the above publication and in Maire and Quézel (1965: 229).

Molecular phylogenetic studies (e.g., Warwick and Sauder, 2005; Warwick and Hall, 2009; Couvreur et al., 2010; Koch and Lemmel, 2019) have clearly demonstrated that *Trachystoma* is polyphyletic and that two of its species—*T. ballii* O.E. Schulz (the generic type) and *T. aphanoneurum* (Maire & Weiller) Maire & Weiller—formed with *C. rapistroides* Coss. & Balansa a strongly supported monophyletic clade. The third species, *T. labasii* Maire, was part of a clade that included *Sinapis arvensis* L. and *S. pubescens* L.

The remarkable similarities in floral, folial, and basic fruit features (e.g., heteroarthrocarpy, indehiscent segments, few- to several-seeded valvular segments), as well as chromosome number, the molecular findings above, and reported fertile hybrids, strongly support the transfer of *Trachystoma ballii* and *T. aphanoneurum* to *Ceratocnemum*. The third species, *T. labasii,* is discussed under *Sinapis*.

Ceratocnemum aphanoneurum (Maire & Weiller) Al-Shehbaz, *comb. nov.*

Basionym: *Sinapis aphanoneura* Maire & Weiller, Bull. Soc. Hist. Nat. Afrique N. 19: 32. 1928.

Ceratocnemum ballii (O.E. Schulz) Al-Shehbaz, *comb. nov.*

Basionym: *Trachystoma ballii* O.E. Schulz, Bot. Jahrb. Syst. 54(3, Beibl. 119): 52. 1916.

Rhamphospermum–Sinapis

In his original description of *Sinapis*, Linnaeus (1753) recognized five species, of which the first two (*S. arvensis* L. and *S. alba* L.) have been maintained in the genus to date. The third and fourth species (*S. nigra* L. and *S. juncea* L.) are currently recognized in *Brassica* L., and the fifth (*S. hispanica* L.) has been kept in *Erucaria* Gaertn. for the past 230 years. As presently delimited in BrassiBase (https://brassibase.cos.uni-heidelberg.de/), the major database of the Brassicaceae, *Sinapis* includes only four species.

All molecular phylogenetic studies of the past two decades that included a good sampling of the most common genera of the tribe Brassiceae (e.g., Warwick and Sauder, 2005; Arias and Pires, 2012; Koch and Lemmel, 2019; and references therein) placed *Sinapis alba* and *S. flexuosa* in a clade clearly unrelated to that including *S. arvensis, S. nigra* (as *Brassica nigra* [L.] W.D.J. Koch), *S. pubescens,* and *Trachystoma labasii*. Extensive cytological data (Warwick and Al-Shehbaz, 2006; updated in BrassiBase) place the above six species in three species pairs, here designated as groups A–C. Group A (*S. alba* and *S. flexuosa*) has $2n = 24$, group B (*S. arvensis* and *S. pubescens*) has $2n = 18$, and group C (*S. nigra* and *T. labasii*) has $2n = 16$. As designated by Green (1925), *S. alba* is the generic type, and therefore *Sinapis* would include only the two species of group A. In all of the above-mentioned molecular studies, groups B and C formed one clade unrelated to that of the herein-circumscribed *Sinapis,* and they should be placed in a separate genus despite slight differences in their chromosome numbers.

The earliest validly published genus, other than *Sinapis*, that included at least one of the four species of groups B and C is *Rhamphospermum* Andrz. ex Besser (Besser, 1822: 83). Its original description listed two species: "Cal. patens, petala erecta, limbo patente. Siliqua sessilis angulata, stylo compresso-conico nervoso, basi monospermo, sponte secedente rostrata. Semina subglobosa, funiculis compressis septo adnatis adfixa uniserialia *Andrz*. Nomen a rostro s. stylo seminifero desumptum: huc. p. 28. n. 851. Sinapis *arvensis* et 1623 *R. orientale* [=*S. orientalis* L.], quod sparsim cum priori occurrit." The mentioning of 1-seeded, conical, slightly compressed stylar segment clearly excluded *S. alba*, which has profoundly compressed, ensiform, seedless distal fruit segment. Although Schulz (1919, 1936) recognized *S. orientalis* as a variety of *S. arvensis*, subsequent students of the Brassicaceae treated it as a minor variant not worth recognition.

As delimited herein, *Rhamphospermum* consists of the four species listed above in groups B and C. *Trachystoma labasii* differs from the other three in having oblong (vs. subglobose) seeds, 1- or 2-seeded (vs. 8- to 16-seeded) valvular segment, and 9- to 11-seeded (vs. 1–4-seeded) terminal segment. However, comparable differences in fruit morphology can be found in small genera of the tribe Brassiceae such as *Ceratocnemum* (see above), *Coincya* Rouy, *Enarthrocarpus* Labill., and *Vella* L., Therefore, the above differences are considered insignificant in the generic placement of *T. labasii*.

The transfer of *Brassica nigra* to another genus would break a traditional, 188-year generic assignment, though the species remained in *Sinapis* for some 50 years following its description by Linnaeus (1753). Every Brassiceae-wide molecular phylogenetic study for the past 30+ years, starting with the pioneering, classic work of Warwick and Black (1991, 1993) and followed by others up to the present (e.g., Warwick and Sauder, 2005; Arias and Pires, 2012; Koch and Lemmel, 2019), concluded that *B. oleracea* ($2n = 18$), the generic type, and *B. nigra* are universally accepted as belonging to the two major and most speciose lineages of the tribe Brassiceae, namely the Oleracea and Nigra lineages, respectively. Together with *B. rapa* L. ($2n = 20$), the above two species formed through ancient interspecific hybridizations among them three allopolyploid species: *B. carinata* A. Braun ($2n = 34$), *B. juncea* (L.) Czern. ($2n =$

36), and *B. napus* L. (2*n* = 38). These six species have long been known as members of the U-triangle named after U (1935) who illucidated their relationships (see also Palmer et al., 1983; Xue et al., 2020).

Therefore, the placement herein of *Brassica nigra* with its three sister species of *Rhamphospermum* is long overdue. In terms of morphology, the former species differs only in having distinctly 1-veined (vs. 3-veined) fruit valves, a feature useful for its separation from the other congeners recognized here. This valve venation is basically the only difference between *Brassica* and *Sinapis*. As briefly given above, *Brassica* is quite heterogeneous in chromosome numbers, and it will have to be split into smaller but monophyletic genera. An excellent initial step, first taken by Gómez-Campo (2002) and extended by German (2015), was to recognize the genus *Guenthera* Andrz. ex Besser. What is most interesting, however, is that both Antoni L. Andrzjowski and Wilibald S. J. G. von Besser were the first to realize nearly two centuries ago that the limits of *Brassica* and *Sinapis* were so heterogeneous that they segregated *Guenthera* and *Rhamphospermum* from them, respectively.

A detailed description of *Rhamphospermum* and a key to its species is presented herein for the first time.

Rhamphospermum Andrz. ex Besser, Enum. Pl. Volhyn., ed. 2: 83. 1822.

Type: *Rhamphospermum arvensis* (L.) Andrz. ex Besser.

Homotypic synonyms: *Agrosinapis* Fourr., Ann. Soc. Linn. Lyon, ser. 2, 16: 329. 1868. TYPE: *A. arvensis* (L.) Fourr.

Sinapistrum Spach, Hist. Nat. Vég. Phan. 6: 343. 1838; non Mill., Gard. Dict. Abr., ed. 4. 1754 [Cleomaceae]; nec F.F.Cheval., Fl. Gén. Env. Paris, ed. 2, 2: 860. 1836. TYPE: *Sinapistrum arvense* (L.) Spach.

Herbs annual. *Trichomes* simple. *Multicellular glands* absent. *Stems* erect to ascending, simple or branched distally, leafy, unarmed. *Basal leaves* petiolate, rosulate or not, simple, lyrate, pinnatifid, or sinuate-dentate, with 1–5 lateral lobes on each side, sometimes undivided and dentate; cauline leaves petiolate or subsessile, cuneate, not auriculate at base, dentate. *Racemes* several to many flowered, ebracteate, corymbose, elongated considerably in fruit, secund or not; rachis straight; fruiting pedicels erect to ascending or divaricate, persistent. *Sepals* oblong to linear, free, deciduous, suberect to ascending or spreading, equal or unequal, base of lateral pair saccate or not. *Petals* bright or pale yellow, erect at base, with flaring blade, ascending, to spreading, longer than sepals; blade obovate, apex subemarginate; claw subequaling sepals, glabrous, unappendaged, entire. *Stamens* 6, exserted, suberect, tetradynamous; filaments wingless, unappendaged, glabrous, free; anthers oblong, apex obtuse. *Nectar glands* 4, distinct; median pair ovoid to oblong; lateral pair prismatic or lobed. *Ovules* 8–16(–24) per ovary; placentation parietal. *Fruit* dehiscent, capsular siliques, linear, terete, not inflated, segmented (heteroarthrocarpic); valvular segment dehiscent, well developed and 4- to 16(–24)-seeded, or highly reduced and seedless, torulose, wingless, unappendaged; valves thick papery, 3- to 5(–7)-veined, glabrous or pubescent, not keeled, wingless, unappendaged; distal segment indehiscent, longer or much shorter than valvular segment, conical to subulate or linear, terete or only slightly compressed, seedless or 1- to 12-seeded, wingless, slightly to distinctly corky, unappendaged, sometimes lomentaceous and break apart transversely into 1-seeded corky segments; gynophore absent; replum rounded, visible; septum complete and membranous, or reduced; style < 1 mm long, stout, persistent; stigma capitate, entire or slightly 2-lobed, unappendaged. *Seeds* uniseriate, wingless, globose or oblong, plump; seed coat reticulate, mucilaginous or not when wetted; cotyledons conduplicate.

Distribution: North Africa, Europe, SW and Central Asia; naturalized in Australia, North and South America, and elsewhere in Africa and Asia.

KEY TO THE SPECIES OF *RHAMPHOSPERMUM*

1a. Fruiting raceme secund; petals with dark purple to brown veins; valvular segment aborts and seedless or 1- to 3-seeded; distal segment lomentaceous, to 12-seeded, breaks apart transversely into 1-seeded segments . . . . . 2. *R. labasii*

1b. Fruiting raceme not secund; petal veins yellow, same color as blade; valvular segment dehiscent, several to many seeded, not lomentaceous; distal segment 1- or 2-seeded, not lomentaceous 2

2a. Valves 1-veined; distal segment seedless . . . . . 3. *R. nigrum*

2b. Valves 3- to 5(–7)-veined; distal segment 1- or 2-seeded 3

3a. Annuals; fruit (2–)2.5–4.5(–5.7) cm long, glabrous or retrorsely hairy; terminal segment straight, erect, conical to subulate, 1- or 2-seeded . . . . . 1. *R. arvense*

3b. Perennials; fruit 1.5–2.5 cm long, antrorsely hairy; terminal segment strongly recurved or hooked, cylindrical, 1- to 4-seeded . . . . . 4. *R. pubescens*

1. ***Rhamphospermum arvense*** (L.) Andrz. ex Besser, Enum. Pl. Volhyn., ed. 2: 83. 1822.

Basionym: *Sinapis arvensis* L., Sp. Pl. 2: 668. 1753.

Distribution: native throughout Europe except NE part, North Africa, and SE and Central Asia; naturalized in Australia, North and South America, and elsewhere in Asia and Africa.

Chromosome number: 2*n* = 18.

2. **Rhamphospermum labasii** (Maire) Al-Shehbaz, *comb. nov.*

Basionym: *Trachystoma labasii* Maire, Mém. Soc. Sci. Nat. Maroc 15: 6. 1926.

Distribution: endemic to Morocco.

Chromosome number: 2*n* = 16.

3. **Rhamphospermum nigrum** (L.) Al-Shehbaz, *comb. nov.*

Basionym: *Sinapis nigra* L., Sp. Pl. 2: 668. 1753.

Distribution: native to Austria, Belgium, England, France, Germany, Italy, Greece, the Netherlands, and NW Africa; perhaps native to some parts of Central Europe and SW Asia; naturalized in Northern Europe, Australia, North and South America, and elsewhere in Africa and Asia.

Chromosome number: $2n = 16$.

4. **Rhamphospermum pubescens** (L.) Al-Shehbaz, *comb. nov.*

Basionym: *Sinapis pubescens* L., Mantissa Pl. 95. 1767.

Distribution: Albania, Algeria, SE France, Italy.

Chromosome number: $2n = 18$.

Maire (in Maire and Quézel, 1965) divided the Algerian populations of *Rhamphospermum* (as *Sinapis*) *pubescens* into three subspecies, six varieties, and two forms. I was not able to critically evaluate these infraspecific taxa because of insufficient material, so no infraspecific taxa are recognized here. *Rhamphospermum arvense* is even more widespread and variable, and this variation necessitates critical population-based molecular and morphological studies as well before any meaningful infraspecific taxonomy is adopted.

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