Phytotaxa 178 (4): 287–297
www.mapress.com/phytotaxa/

Article

ISSN 1179-3155 (print edition)
PHYTOTAXA
ISSN 1179-3163 (online edition)

http://dx.doi.org/10.11646/phytotaxa.178.4.2

Phylogenetic position and taxonomic assignment of *Thlaspi aghricum* P.H.Davis & K.Tan (Brassicaceae)

MEHMET FIRAT[1], BARIŞ ÖZÜDOĞRU[2], BURCU TARIKAHYA-HACIOĞLU[3], ALI SAVAŞ BÜLBÜL[4], IHSAN A. AL-SHEHBAZ[5]* & KLAUS MUMMENHOFF[6]

[1*]*Department of Biology Education, Faculty of Education, Van Yüzüncüyıl University, Van, Turkey.*
[2]*Department of Biology, Faculty of Science, Hacettepe University, Beytepe, Ankara 06800, Turkey.*
[3] *Central Research Institute for Field Crops, Republic of Turkey Ministry of Food Agriculture and Livestock, Ankara, Turkey.*
[4] *Department of Molecular Biology and Genetics, Faculty of Science, Bartın University, 74100 Bartın, Turkey.*
[5*]*Missouri Botanical Garden, P.O. Box 299, St. Louis, Missouri 63166-0299, U.S.A. Ihsan.Al-Shehbaz@mobot.org.*
[6] *University Osnabrück, D-49076 Osnabrück, Germany.*
[*] *Author for correspondence*

Abstract

A general review of the taxonomic status of *Thlaspi* past and present is given, and a critical evaluations of its segregates based on both morphological and molecular data are presented. ITS molecular phylogenetic study of *Thlaspi aghricum* and related species, as well as seed-coat morphology and anatomy strongly support the placement of the species in *Noccaea.* The new combination *N. aghrica* is proposed, and detailed description and distribution of the species are given.

Key words: Brassicaceae, Cruciferae, *Noccaea, Thlaspi,* seed

Introduction

The genus *Thlaspi* L. s.l. was once considered among the larger genera of Brassicaceae (Cruciferae) and consisted of approximately 75 species (Al-Shehbaz 1986). However, a radical revision of the genus was proposed by Meyer (1973, 1979) based almost solely on seed-coat anatomy. He relied on differences in the outer and inner epidermal cells of the outer integument and divided the genus into 12 genera and retained only six species in *Thlaspi* s.str. The taxonomic status of Meyer's segregates was completely rejected (Greuter *et al.* 1986), partially accepted (Al-Shehbaz 2002, 2012), or completely accepted (Czerepanov 1995). Furthermore, Meyer's segregates were subjected to several molecular studies (e.g., Mummenhoff & Koch 1994; Koch & Mummenhoff 2001; Khosravi *et al.* 2008) that demonstrated the monophyly of some of them and polyphyly of others.

More recent works (e.g., Al-Shehbaz *et al.* 2006; Bailey *et al.* 2006; Koch *et al.* 2007; Couvreur *et al.* 2010; Warwick *et al.* 2010, 2011) clearly demonstrated that *Thlaspi* s.str., belongs to the tribe Thlaspideae (expanded lineage II), *Noccidium* F.K.Mey. to the Camelineae (lineage I), and the remaining segregates to the Noccaeeae (hereafter Coluteocarpeae) (expanded lineage II). These findings fully agree with the latest available data currently available on BrassiBase, an up-to-date database on the Brassicaceae (Kiefer *et al.* 2014; Koch *et al.* 2012; Koch & German 2013). Finally, Al-Shehbaz (2012) suggested that all *Thlaspi* segregates, except for *Noccidium* and *Thlaspi* s.str., should be subsumed under genus *Noccaea* Moench, but their species then were not formally transferred to the latter genus, though they have recently been proposed (Al-Shehbaz 2014). The lack of both morphological and molecular data to support *Noccaea* as consistently distinct from Meyer's (1973, 1979) segregates of *Thlaspi* led us to adopt a generic concept for *Noccaea* broader than Meyer's. Therefore, the discussions hereafter will deal with *Noccaea* sensu Al-Shehbaz (2012, 2014).

Many species previously assigned to *Thlaspi,* including *T. aghricum* P.H.Davis & K.Tan (Fig. 1), remained unstudied molecularly to determine their tribal affiliation and generic status. This East Anatolian endemic was originally known from only two localities in Ağrı Province, but a third-locality from Siirt Province is added herein. Davis and Tan (in Davis *et al.* 1988) considered *T. aghricum* to be closely related to *T. lilacinum* Boiss. & A.Huet, a species transferred by Meyer (1973, 1979) to *Callothlaspi* F.K.Mey.

Accepted by Karol Marhold: 6 Aug. 2014; published: 19 Sept. 2014

References

Al-Shehbaz, I. A. (1986) The genera of Lepidieae (Cruciferae, Brassicaceae) in the southeastern United States. *Journal of the Arnold Arboretum* 67: 265–311.

Al-Shehbaz, I. A. (2002) *Noccaea nepalensis*, a new species from Nepal, and four new combinations in *Noccaea* (Brassicaceae). *Adansonia* 24: 89–92.

Al-Shehbaz, I. A. (2012) A generic and tribal synopsis of the Brassicaceae (Cruciferae). *Taxon* 61: 931–954.

Al-Shehbaz, I. A. (2014) A synopsis of the genus *Noccaea* (Brassicaceae: Coluteocarpeae). *Harvard Papers in Botany* 19, in press). http://dx.doi.org/10.3100/hpib.v19iss1.2014.n3

Al-Shehbaz, I. A., Beilstein M.A. & Kellogg E.A. (2006) Systematics and phylogeny of the Brassicaceae: An overview. *Plant Systematics and Evolution* 259: 89–120. http://dx.doi.org/10.1007/s00606-006-0415-z

Aytaç, Z., Nordt B. & Parolly G. (2006) A new species of *Noccaea* (Brassicaceae) from South Anatolia, Turkey. *Botanical Journal of the Linnean Society* 150: 409–416. http://dx.doi.org/10.1111/j.1095-8339.2006.00472.x

Bailey, C.D., Koch, M.A., Mayer, M., Mummenhoff, K., O'Kane, S.L., Jr., Warwick, S.I., Windham, M.D. & Al-Shehbaz, I.A. (2006) Toward a global phylogeny of the Brassicaceae. *Molecular Biology and Evolution* 23: 2142–2160. http://dx.doi.org/10.1093/molbev/msl087

Couvreur, T.L., Franzke, A., Al-Shehbaz, I.A., Bakker, F.T., Koch, M.A. & Mummenhoff, K. (2010) Molecular phylogenetics, temporal diversification, and principles of evolution in the mustard family (Brassicaceae). *Molecular Biology and Evolution* 27: 55–71. http://dx.doi.org/10.1093/molbev/msp202

Czerepanov, S.K. (1995) *Vascular plants of Russia and adjacent states (the former USSR)*. Oxford: Oxford University Press.

Davis, P.H., Mill, R.R. & Tan, K. (eds) (1988) *Flora of Turkey and the East Aegean Islands.* Vol. 10. Edinburgh: Edinburgh University Press.

Drummond, A.J., Suchard, M.A., Xie, D. & Rambaut, A. (2012). Bayesian Phylogenetics with BEAUti and the BEAST 1.7. *Molecular Biology and Evolution* 29: 1969–1973. http://dx.doi.org/10.1093/molbev/mss075

Edgar, R.C. (2004) MUSCLE: Multiple sequence alignments with high accuracy and high throughput. *Nucleic Acids Research* 32: 1792–1797. http://dx.doi.org/10.1093/nar/gkh340

Ekim, T., Koyuncu, M., Vural M., Duman, H., Aytaç, Z. & Adıgüzel, N. (2000). *Red data book of Turkish plants (Pteridophyta and Spermatophyta).* Ankara: Turkish Association for the Conservation of Nature and Van Centennial University.

Franzke, A., Lysak, M.A., Al-Shehbaz, I.A, Koch, M.A., Mummenhoff, K. (2011) Cabbage family affairs: The evolutionary history of Brassicaceae. *Trends in Plant Science* 16: 108–116. http://dx.doi.org/10.1016/j.tplants.2010.11.005

Fırat, M. (2013) *Ferhenga Navén Rıwekén Bı Kurdi /Kürtçe Bitki Adları Sözlüğü / Dictionary of Plant Names in Kurdish,* Ankara, Kalkan Ofset.

Greuter, W., Burdet, H. M. & G. Long. (eds.). (1986) Med-checklist, Dicotyledones, Cruciferae. 3: 34–172. *Conservatoire et Jardin Botaniques de la ville de Genéve*, OPTIMA, Genéve.

IUCN (2001) *IUCN Red List Categories and Criteria: Version 3.1.* IUCN species Survival Commission. IUCN, Gland, Switzerland and Cambridge, U.K..

Khosravi, R., Mohsenzadeh, S. & Mummenhoff, K. (2008) Phylogenetic position of *Brossardia papyracea* (Brassicaceae) based on sequences of nuclear ribosomal DNA. *Feddes Repertorium* 119: 13–23. http://dx.doi.org/10.1002/fedr.200811146

Kiefer, M., Schmickl, R., German, D. A., Mandáková, T., Lysak, M. A., Al-Shehbaz, I. A., Franzke, A.. Mummenhoff, K., Stamatakis, A. & Koch. M. A. (2014) BrassiBase: Introduction to a novel knowledge database on Brassicaceae evolution. *Plant Cell Physiology* 55(1): e3(1–9). doi:10.1093/pcp/pct158. http://dx.doi.org/10.1093/pcp/pct158

Koch, M. & Mummenhoff, K. (2001) *Thlaspi* s.str. (Brassicaceae) versus *Thlaspi* s.l.: Morphological and anatomical characters in the light of ITS nrDNA sequence data. *Plant Systematics and Evolution* 227: 209–225. http://dx.doi.org/10.1007/s006060170049

Koch, M. & Al-Shehbaz, I.A. (2002) Molecular data indicate complex intra- and intercontinental differentiation of American Draba (Brassicaceae). *Annals of the Missouri Botanical Garden* 89: 88–109. http://dx.doi.org/10.2307/3298659

Koch, M. & Al-Shehbaz, I. A. (2004) Taxonomic and phylogenetic evaluation of the American *'Thlaspi'* species: Identity and relationship to the Eurasian genus *Noccaea* (Brassicaceae). *Systematic Botany* 29: 375–384.
http://dx.doi.org/10.1600/036364404774195566

Koch, M. A. & German, D. A. (2013) Taxonomy and systematics are key to biological information: *Arabidopsis, Eutrema (Thellungiella), Noccaea* and *Schrenkiella* (Brassicaceae) as examples. Frontiers in Pl. Science,
http://dx.doi.org/10.3389/fpls.2013.00267

Koch, M.,_Dobeš, C., Keifer, C., Schmickl, R., Klimeš, L. & Lysak, M.A. (2007) Supernetwork identifies multiple events of plastid trnF(GAA) pseudogene evolution in the Brassicaceae. *Molecular Biology and Evolution* 24: 63–73.
http://dx.doi.org/10.1093/molbev/msl130

Koch, M. A., Kiefer, M., German, D. A., Al-Shehbaz, I. A., Franzke, A., Mummenhoff, K. & R. Schmickl (2012). *BrassiBase:* Tools and biological resources to study characters and traints in the Brassicaceae – version 1.1. *Taxon* 61: 1001–1009.

Kropf, M., Kadereit, J.W. & Comes, H.P. (2003) Differential cycles of range contraction and expansion in European high mountain plants during the Late Quaternary: Insights from Pritzelago alpina (L.) O. Kuntze (Brassicaceae). *Molecular Ecology* 12: 931–949.
http://dx.doi.org/10.1046/j.1365-294X.2003.01781.x

Mengoni, A., Baker, A.J.M., Bazzicalupo, M., Reeves, R.D., Adigüzel, N., Chianni, E., Galardi, F., Gabbriella, R. & Gonnelli, C. (2003). Evolutionary dynamics of nickel hyperaccumulation in Alyssum revealed by ITS nrDNA analysis. *New Phytologist* 159: 691–699.
http://dx.doi.org/10.1046/j.1469-8137.2003.00837.x

Meyer, F. K. (1973) Conspectus der "*Thlaspi"*-Arten Europas, Afrikas und Vorderasiens. *Feddes Repertorium* 84: 449–470.
http://dx.doi.org/10.1002/fedr.19730840503

Meyer, F. K. (1979) Kritische Revision der "*Thlaspi"*-Arten Europas, Afrikas und Vorderasiens. *Feddes Repertorium* 90: 129–154.
http://dx.doi.org/10.1002/fedr.19790900302

Meyer, F. K. (1991) Seed-coat anatomy as a character for a new classification of *Thlaspi*. *Flora et Vegeation Mundi* 9: 9–15.

Meyer, F. K. & Heenan, P.B. (2000) Systematic relationships of New Zealand endemic Brassicaceae inferred from nrDNA ITS sequence data. *Systematic Botany* 25: 98–105.
http://dx.doi.org/10.2307/2666676

Mummenhoff, K. & Koch, M.A. (1994) Chloroplast DNA restriction site variation and phylogenetic relationships in the genus *Thlaspi* sensu lato (Brassicaceae). *Systematic Botany* 19: 73–88.
http://dx.doi.org/10.2307/2419713

Mummenhoff, K., Linder, P., Friesen, N., Bowman, J.L., Lee, J.Y. & Franzke, A. (2004) Molecular evidence for bicontinental hybridogenous genome constitution in Lepidium sensu stricto (Brassicaceae) species from Australia and New Zealand. *American Journal of Botany* 91: 254–261.
http://dx.doi.org/10.3732/ajb.91.2.254

Mummenhoff, K., Al-Shehbaz, I.A., Bakker, F.T., Linder, H.P. & Mühlhaussen. A. (2005). Phylogeny, morphological evolution, and speciation of endemic Brassicaceae genera in the Cape flora of southern Africa. *Annals of the Missouri Botanical Garden* 92: 400–424.

O'Brien, T. P., Feder, N. & McCully, M.E. (1964) Polychromatic staining of plant cell walls by toluidine blue. *Protoplasma* 59: 368–373.
http://dx.doi.org/10.1007/BF01248568

O'Kane, S.L., Jr. & Al-Shehbaz, I.A. (2003) Phylogenetic position and generic limits of Arabidopsis (Brassicaceae) based on sequences of nuclear ribosomal DNA. *Annals of the Missouri Botanical Garden* 90: 603–612.
http://dx.doi.org/10.2307/3298545

Peer, W.A., Mamoudian, M., Lahner, B., Reeves, R.D., Murphy A.S. & Salt, D.E. (2003) Identifying model metal hyperaccumulating plants: germplasm analysis of 20 Brassicaceae accessions from a wide geographical area. *New Phytologist* 159: 421–430.
http://dx.doi.org/10.1046/j.1469-8137.2003.00822.x

Rambaut, A. & Drummond A.J. (2007) Tracer, version 1.4. Available from http:// beast.bio.ed.ac.uk/Tracer

Resetnik, I., Satovic, Z., Schneeweiss, G.M. & Liber, Z. (2013) Phylogenetic relationships in Brassicaceae tribe Alysseae inferred from nuclear ribosomal and chloroplast DNA sequence data. *Molecular Phylogenetics and Evolution* 69: 772–786.
http://dx.doi.org/10.1016/j.ympev.2013.06.026

Swofford, D.L. (2000) *PAUP*. Phylogenetic Analysis Using Parsimony (*and other methods), Vers. 4*. Sinauer, Sunderland, Massachusetts.

Tamura, K., Peterson, D., Peterson, N., Stecher, G., Nei, M. & Kumar, S. (2011). MEGA5: molecular evolutionary genetics analysis using maximum likelihood, evolutionary distance, and maximum parsimony methods. *Molecular Biology and Evolution* 28: 2731–2739.
http://dx.doi.org/10.1093/molbev/msr121

Vaughan, J.G. & Whitehouse J.M. (1971) Seed structure and the taxonomy of the Cruciferae. *Botanical Journal of the Linnean Society*

64: 383–409.
http://dx.doi.org/10.1111/j.1095-8339.1971.tb02153.x

Warwick, S.I., Al-Shehbaz, I.A., Price, R.A. & Sauder, C. (2002) Phylogeny of *Sisymbrium* (Brassicaceae) based on ITS sequences of nuclear ribosomal DNA. *Canadian Journal of Botany* 80: 1002–1017.
http://dx.doi.org/10.1139/b02-089

Warwick, S.I., Al-Shehbaz, I.A., Sauder, C.A., Murray, D.F. & Mummenhoff, K. (2004) Phylogeny of *Smelowskia* and related genera (Brassicaceae) based on nuclear ITS DNA and chloroplast trnL intron DNA sequences. *Annals of the Missouri Botanical Garden* 91: 99–123.

Warwick, S.I. & Sauder, C. (2005) Phylogeny of tribe Brassiceae based on chloroplast restriction site polymorphisms and nuclear ribosomal internal transcribed spacer (ITS) and chloroplast trnL intron sequences. *Canadian Journal of Botany* 83: 467–483.
http://dx.doi.org/10.1139/b05-021

Warwick, S.I., Francis, A. & Al-Shehbaz, I.A. (2006) Brassicaceae: Species Checklist and database on CD-Rom. *Plant Systematics and Evolution* 259:249–258.
http://dx.doi.org/10.1007/s00606-006-0422-0

Warwick, S.I., Sauder, C., Al-Shehbaz, I.A. & Jacquemoud, F. (2007) Phylogenetic relationships in the Brassicaceae tribes Anchonieae, Chorisporeae, Euclidieae, and Hesperideae based on
nuclear ribosomal ITS DNA sequences. *Annals of the Missouri Botanical Garden* 94: 56–78.
http://dx.doi.org/10.3417/0026-6493(2007)94[56:PRITTA]2.0.CO;2

Warwick, S.I., Sauder, C.A. & Al-Shehbaz, I.A. (2008) Phylogenetic relationships in the tribe Alysseae (Brassicaceae) based on nuclear ribosomal ITS DNA sequences. *Canadian Journal of Botany* 86: 315–336.
http://dx.doi.org/10.1139/B08-013

Warwick, S.I., Sauder, C.A., Mayer, M.S. & Al-Shehbaz, I.A. (2009) Phylogenetic relationships in the tribes Schizopetaleae and Thelypodieae (Brassicaceae) based on nuclear ribosomal ITS region and chloroplast ndhF DNA sequences. *Botany* 87: 961–985.
http://dx.doi.org/10.1139/B09-051

Warwick, S.I., Mummenhoff, K., Sauder, C.A., Koch M.A. & Al- Shehbaz, I.A. (2010) Closing the gaps: phylogenetic relationships in the Brassicaceae based on DNA sequence data of nuclear ribosomal ITS region. *Plant Systematics and Evolution* 285: 209–232.
http://dx.doi.org/10.1007/s00606-010-0271-8

Warwick, S.I., Sauder C.A. & Al-Shehbaz, I.A. (2011) Systematic position of *Ivania*, *Scoliaxon*, and *Phravenia* (Brassicaceae). *Taxon* 60: 1156–1164.

White, T.J., Bruns, T., Lee, S. & Taylor, J. (1990) Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. *In* Innis, M.A., Gelfand, D.H., Sninsky, J.J. & White, T.J. (eds.) *PCR protocols*. Academic Press, New York, pp. 315–322

APPENDIX I

Alyssum montanum L., AY237938 (Mengoni *et al.* 2003). *Aphragmus eschscholtzianus* Andrz., DQ165334 (Warwick *et al.* 2006). *Aphragmus hobsonii* (H. Pears.) Al-Shehbaz & S.I. Warwick, DQ165357 (Warwick *et al.* 2006). *Arabis alpina* L., AF137559 (O'Kane & Al-Shehbaz 2003). *Asta schaffneri* (S.Watson) O.E.Schulz, GQ497848 (Warwick *et al.* 2010). *Asta stricta* Rollins, Paray HQ541171 (Warwick *et al.* 2011). *Berteroa incana* (L.) DC., EF514632 (Warwick *et al*. 2008). *Bivonaea lutea* (Bivona-Bernardi) DC., HQ327490 (Koch, unpub.). *Boreava orientalis* Jaub. & Spach, DQ249859 (Koch *et al*. 2007). *Brassica oleracea* L., AY722423 (Warwick & Sauder, 2005). *Brayopsis colombiana* Al-Shehbaz, EU620283 (Warwick *et al*. 2009). *Calepina irregularis* (Asso) Thell., DQ249822 (Koch *et al.* 2007). *Camelina microcarpa* Andrz. ex DC., AF137574 (O'Kane & Al-Shehbaz, 2003). *Chalcanthus renifolius* (Boiss. & Hohen.) Boiss., GQ424528 (Couvreur *et al.* 2010). *Cochlearia megalosperma* (Maire) Vogt, AF336208 and AF336209 (Koch & Mummenhoff, 2001). *Cochlearia sempervivum* Boiss. & Balansa, AY261529.1 (Peer *et al*. 2003) [*Pseudosempervivum sempervivum* (Boiss. & Balansa) Pobed.]. *Coluteocarpus vesicaria* (L.) Holmboe, GQ497857.1 (Warwick *et al.* 2010) *Conringia clavata* Boiss., AY722505 (Warwick & Sauder, 2005). *Cremolobus chilensis* (Lag. ex DC.) DC., GQ424530 (Couvreur *et al.* 2010). *Draba aizoides* L., AF146512 (Koch and Al-Shehbaz, 2002). *Eudema nubigena* Humb. & Bonpl., EU620297 (Warwick *et al.* 2009). *Eutrema altaicum* (C.A.Mey.) Al-Shehbaz & S.I. Warwick, DQ165364 (Warwick *et al.* 2006). *Goldbachia laevigata* (M.Bieb.) DC., DQ357545 (Warwick *et al.* 2007). *Graellsia saxifragifolia* (DC.) Boiss., GQ424572 (Couvreur *et al.* 2010). *Heliophila arenaria* Sond., AJ863600 and AJ864811 (Mummenhoff *et al.* 2005). *Heliophila subulata* Burch. ex DC., AJ863580 and AJ864835 (Mummenhoff *et al.* 2005). *Hesperidanthus linearifolius* (A.Gray) Rydb., AF531612 (Warwick *et al.* 2002). *Hesperis matronalis*