Guide to Wild Germplasm of Brassica and Allied Crops (tribe Brassiceae, Brassicaceae) 3rd Edition

by

Warwick[1] S.I., Francis[1] A. and Gugel[2] R.K. (2009)

[1] Agriculture and Agri-Food Canada (AAFC), Eastern Cereal and Oilseeds Research Centre, K.W. Neatby Bldg., Central Experimental Farm, Ottawa, Ontario, Canada K1A 0C6 Contact: Suzanne.Warwick@AGR.GC.CA

[2] AAFC, Saskatoon Research Centre, 107 Science Place, Saskatoon, Saskatchewan, Canada SN7 0X2

Introduction to the Guide to Wild Germplasm of Brassica and Allied Crops (tribe Brassiceae, Brassicaceae) 3rd Edition

This edition provides an update to the electronic 2000 Edition 2 of the Guide, which in turn had replaced the 1993-94 publications “Guide to the Wild Germplasm of *Brassica* and Allied Crops (Tribe Brassiceae, family Cruciferae) Parts I to V” (Warwick, 1993a,b; Warwick and Anderson, 1993; Warwick and Black, 1993a; Warwick and Francis, 1994). The taxonomic checklist and geographical and ecological data on the currently accepted species in the tribe Brassiceae are now combined in Part I of the Guide. Taxonomic revisions are based on Warwick et al. (2006). Additions to ecological and geographical data are based on recently available flora, added to the references. Part II on chromosome numbers has been expanded to include additional information and references based on Warwick and Al-Shehbaz (2006). In Part III, inter-specific and inter-generic hybridization reports from 78 recently published sources have been added to the 384 references listed in Edition 2. [In Part IV, potential agronomic traits have been expanded to include the whole family. The information provided in this guide is intended to be useful in providing direction for future genebank needs for these crops and for assisting biotechnologists and plant breeders in the utilization of these genetic resources in their research programs. It is also an extremely valuable resource for regulators concerned with the possibility of gene flow between transgenic cruciferous crops and wild relatives not only in Canada but on a global basis.

Edition 3 of the Guide to the Wild Germplasm of Brassica and Allied Crops (Tribe Brassiceae, Brassicaceae) has been divided into four separate pdf files, each with its own list of references, which can be downloaded and printed separately.

I. Taxonomic Checklist and Life History, Ecological, and Geographical Data

II. Chromosome Numbers

III. Interspecific and Intergeneric Hybridization Data

IV. Wild Species as Sources of Agronomic Traits

Guide to Wild Germplasm of Brassica and Allied Crops (Tribe Brassiceae, Brassicaceae): Introduction

Taxonomy of the Tribe

The Brassicaceae, which currently includes 3709 species and 338 genera (Warwick et al. 2006), is one of the ten most economically important plant families (Rich 1991). The tribe Brassiceae is one of the 13-19 tribes which have been recognized within the family and is one of the few tribes believed to constitute a natural group (Hedge 1976, Al-Shehbaz 1984, 1985). It is the most important economically and the most distinctive (Gómez-Campo 1980, 1999; Al-Shehbaz 1985). It is distinguished on the basis of the presence of conduplicate cotyledons (i.e. the cotyledons are longitudinally folded around the radical) and/or two-segmented fruits (siliques) which contain seeds in one or both segments, and only simple hairs, if present (Gómez-Campo 1980, 1999; Al-Shehbaz 1985).

Crop brassicas display enormous diversity and are used as a source of oil, vegetables, mustard condiments, and fodder. Those of particular importance in Canada are: *Brassica napus*, *B. rapa*, and *B. juncea* as sources of canola oil, and *B. oleracea* as cole-crops. The genera *Raphanus* and *Sinapis* are also of major importance, the former cultivated for its edible roots and the latter as a source of mustard condiments along with *B. nigra.* Several species have become naturalized weeds in Canada and the United States [e.g. *Sinapis arvensis* (wild mustard), *Raphanus raphanistrum* (wild radish), and *B. rapa* (wild rape)], representing both a potential source of germplasm and agricultural problems. In other areas of the world *Crambe* is cultivated as an industrial oil, and the leaves of other genera (e.g. *Eruca* and *Diplotaxis*) are eaten as salad greens.

An understanding of the genetic potential of wild relatives of the crop species of *Brassica* and allied genera (members of the Tribe Brassiceae) is critical for the establishment of long-term breeding programs for these crops. In addition, it is clear that many of the wild species in the tribe have potential value as new crops, as sources of industrial oils (*Crambe*, *Eruca*), condiments (*Sinapis alba*), and other diverse products, and/or as host systems for molecular farming. Wild relatives also possess a number of useful agronomic traits which could be incorporated into breeding programs, including: cytoplasmic and nuclear male sterility; resistance to disease and insect and nematode pests; intermediate C_3-C_4 photosynthetic activity; and tolerance of cold, salt and drought conditions.

The last comprehensive taxonomic treatment of the tribe was conducted by Schulz (1919, 1923, 1936). The tribe Brassiceae currently contains 242 species in 48 genera, 20 of which are monotypic (Table below). Geographically, it is centred in the southwestern Mediterranean region, particularly Algeria, Morocco and Spain, where *c.* 40 genera are either endemic or exhibit maximum diversity. The tribal range extends eastward into India and Pakistan and southward into South Africa, with a poor representation in the New World (Hedge 1976, Gómez-Campo 1980, 1999; Al-Shehbaz 1985).

Within the tribe, Schulz (1919, 1923, 1936) also recognized, somewhat arbitrarily on the basis of morphological characters, seven subtribes: Brassicinae, Cakilinae, Moricandiinae, Raphaninae, Savignyinae, Vellinae, and Zillinae. The Brassicinae and Moricandiinae both include genera with elongated siliquose dehiscent fruit, while the other subtribes include those with reduced or "nucamentaceous" fruits.

Generic boundaries in the tribe are still somewhat arbitrarily drawn, and the establishment of clear-cut intergeneric relationships requires clarification. The species are generally very distinct throughout the family, with fruit characters being the most reliably used structures for the proper identification of genera and species. Taxonomic debate on the tribe has centred most particularly upon the number of and relationships between the subtribes and genera (Hedge 1976, Al-Shehbaz 1985). Recent changes include the placement of the genera *Euzomodendron* in *Vella* and *Coincya* (Warwick and Al-Shehbaz 1998; Warwick et al. 2006); and of *Hirschfeldia* in Sinapis and other genera (Warwick et al. 2006); of the monotypic genera *Dolichorhynchus* in *Douepea* (Appel & Al-Shehbaz 2003) and of *Quidproquo* in Raphanus (Al-Shehbaz and Warwick 1997); and the exclusion of the genera *Calepina* and *Spryginia*. (Gomez-Campo 1980; Warwick & Sauder 2005).

GENERA OF THE TRIBE BRASSICEAE (no. species in brackets)

Ammosperma (2)
Brassica (39)
Cakile (6)
Carrichtera (1)
Ceratocnemum (1)
Chalcanthus (1)
Coincya (6)
Conringia (6)
Cordylocarpus (1)
Crambe (34)
Crambella (1)
Didesmus (2)
Diplotaxis (32)
Douepea (2)
Enarthrocarpus (5)
Eremophyton (1)
Eruca (4)
Erucaria (10)
Erucastrum (25)
Fezia (1)
Foleyola (1)
Fortuynia (2)
Guiraoa (1)
Hemicrambe (3)
Henophyton (2)
Kremeriella (1)
Moricandia (8)
Morisia (1)
Muricaria (1)
Orychophragmus (2)
Otocarpus (1)
Physorhynchus (2)
Pseuderucaria (2)
Pseudofortuynia (1)
Psychine (1)
Quezeliantha (1)
Raffenaldia (2)
Raphanus (3)
Rapistrum (2)
Rytidocarpus (1)
Savignya (1)
Schouwia (1)
Sinapidendron (4)
Sinapis (5)
Succowia (1)
Trachystoma (3)
Vella (7)
Zilla (2)

The genus *Brassica* is one of ten core genera in the subtribe Brassicinae, which also includes *Coincya*, *Diplotaxis*, *Eruca*, *Erucastrum*, *Raphanus*, *Sinapidendron*, *Sinapis*, and *Trachystoma*. The Brassicinae is defined primarily on the basis of elongated (siliquose) dehiscent fruits, presence of median nectaries, and usually seeded beaks. Although morphologically quite distinct from subtribes Cakilinae, Vellinae, and Zillinae, its separation from the Raphaninae and Moricandiinae is not well supported by morphological, hybridization or molecular data. Current generic circumscriptions within the subtribe Brassicinae have also been considered to be highly artificial by many taxonomists, with generic delimitation based primarily on only one or two morphological traits. Recent data support the inclusion of members of these two subtribes, e.g. *Moricandia*, *Raphanus*, within subtribe Brassicinae.

Systematists are continuing to re-evaluate relationships within the tribe Brassiceae by way of morphological, cytological, hybridization, isozyme and molecular analyses (studies reviewed in Warwick and Black 1991, 1993b, 1994, 1997; Anderson and Warwick, 1999; Francisco–Ortega et al. 1999, Gómez-Campo 1999)). Such research has confirmed many proposed species relationships, but has also indicated new relationships between genera and species. In particular, these studies have identified new potential sources of germplasm for *Brassica* crops, indicating that the range of germplasm important to the genus is much greater than previously recognized.

References

Al-Shehbaz, I.A. 1984. The tribes of Cruciferae (Brassicaceae) in the southeastern United States. J. Arnold Arbor. 65: 343-373.

Al-Shehbaz, I.A. 1985. The genera of Brassiceae (Cruciferae: Brassicaceae) in the southeastern United States. J. Arnold Arbor. 66: 279-351.

Al-Shehbaz, I.A. and Warwick, S.I. .1997. The generic disposition of *Quidproquo confusum* and *Sinapis aucheri* (Brassicaceae). Novon 7: 219-220.

Anderson, J.K. and Warwick, S.I. 1999. Chromosome number evolution in the tribe Brassiceae (Brassicaceae); evidence from isozyme number. Pl. Syst. Evol. 215: 255-285.

Appel, O. and Al-Shehbaz, I.A. 2003. Cruciferae. In: K. Kubitzki (ed.), Families and genera of vascular plants, vol. 5. Springer, Berlin. pp. 75-174.

Francisco–Ortega, J., Fuertes-Aguilar, J., Gómez-Campo, C., Santos-Guerra,, A. Kim, S.-C., Crawford, D.J. and Jansen, R.K. 1999. Internal transcribed spacer sequence phylogeny of *Crambe* L. (Brassicaceae): molecular data reveal two Old World disjunctions. Mol. Phylogenet. Evol. 11: 361-380.

Gómez-Campo, C. 1980. Studies on Cruciferae: VI. Geographical distribution and conservation status of *Boleum* Desv., *Guiraoa* Coss. and *Euzomodendron* Coss. Anales Inst. Bot. Cavanilles 35: 165-176.

Gómez-Campo, C. 1999. Biology of Brassica Coenospecies. Developments in Plant Genetics and Breeding. Elsevier Science B.V. 490 pp.

Hedge, I.C. 1976. A systematic and geographical survey of the Old World Cruciferae. *In*: J.G. Vaughn, A.J. MacLeod and B.M.G. Jones (eds.), The biology and chemistry of the Cruciferae. Academic Press, London. pp. 1-45.

Rich, T.C.G. 1991. Crucifers of Great Britain and Ireland. Botanical Society of the British Isles, London. 336 pp.

Schulz, O.E. 1919. IV. 105 Cruciferae-Brassiceae. Part 1. Subtribes Brassicinae and Raphaninae. *In:* A. Engler, (ed.), Das Pflanzenreich, Heft 68-70, Wilhelm Engelmann, Leipzig. pp. 1-290.

Schulz, O.E. 1923. IV. 105. Cruciferae-Brassiceae. Part II. Subtribes Cakilinae, Zillinae, Vellinae, Savignyinae and Moricandiinae. *In:* A. Engler (ed.), Das Pflanzenreich, Heft 82-85, Wilhelm Engelmann, Leipzig. pp. 1-100.

Schulz O.E. 1936. Cruciferae-Brassicaceae. *In*: A. Engler and H. Harms (eds.), Die Natürlichen Pflanzenfamilien, 2nd ed., Band 17-b. Wilhelm Engelmann, Leipzig. pp. 227-658.

Warwick, S.I. 1993a. Guide to the wild germplasm of *Brassica* and allied crops. Part I. Taxonomy and genome status in the Tribe Brassiceae (Cruciferae). Agriculture Canada Research Branch, Technical Bulletin 1993-14E, Ottawa, Canada. 33 pp.

Warwick, S.I. 1993b. Guide to the wild germplasm of *Brassica* and allied crops. Part IV. Wild species in the Tribe Brassiceae (Cruciferae) as sources of agronomic traits. Agriculture Canada Research Branch, Technical Bulletin 1993-17E, Ottawa, Canada. 19 pp.

Warwick, S.I. and Al-Shehbaz, I.A. 1998. Generic evaluation of *Boleum*, *Euzomodendron* and *Vella* (Brassicaceae) Novon 8: 321-325.

Warwick, S.I. and Al-Shehbaz, I.A. 2006. Brassicaceae: chromosome number index and database on CD-ROM. Pl. Syst. Evol. 259: 237–248.

Warwick, S.I. and Anderson, J.K. 1993. Guide to the wild germplasm of Brassica and allied crops. Part II. Chromosome numbers in the Tribe Brassiceae (Cruciferae). Agriculture Canada Research Branch, Technical Bulletin 1993-15E, Ottawa, Canada. 22 pp.

Warwick, S.I. and Black, L.D. 1991. Molecular systematics of *Brassica* and allied genera (Subtribe Brassicinae, Brassiceae) - chloroplast genome and cytodeme congruence. Theor. Appl. Genet. 82: 81-92.

Warwick, S.I. and Black, L.D. (1993a) Guide to the wild germplasm of *Brassica* and allied crops. Part III. Interspecific and intergeneric hybridization in the tribe Brassicaceae (Cruciferae). Agriculture Canada Research Branch,

Technical Bulletin 1993-16E, Ottawa Canada. 31 pp.

Warwick, S.I. and Black, L.D. 1993b. Molecular relationships in subtribe Brassicinae (Cruciferae, tribe Brassiceae). Can. J. Bot. 71: 906-918.

Warwick, S. I. and Black, L.D. 1994. Evaluation of the subtribes Moricandiinae, Savignyinae, Vellinae and Zillinae (Brassicaceae, tribe Brassiceae) using chloroplast DNA restriction site variation. Can. J. Bot. 72: 1692-1701.

Warwick, S. I. and Black, L.D. 1997. Phylogenetic implications of chloroplast DNA restriction site variation in subtribes Raphaninae and Cakilinae (Brassicaceae, tribe Brassiceae). Can. J. Bot. 75: 960-973.

Warwick, S.I. and Francis, A. 1994. Guide to the wild germplasm of *Brassica* and allied crops. Part V. Life History and Geographical Data for Wild Species in the Tribe Brassiceae (Cruciferae). Agriculture Canada Research Branch, Technical Bulletin 1994-2E, Ottawa, Canada. 61pp.

Warwick, S.I. and Sauder, C.A. 2005. Phylogeny of the tribe Brassiceae (Brassicaceae) based on chloroplast restriction site polymorphisms and nuclear ribosomal internal transcribed spacer and chloroplast *trn*L intron sequences. Can. J. Bot. 83: 467-483.

Warwick, S.I., Francis, A. and Al-Shehbaz, I.A. 2006. Brassicaceae: species checklist and database on CD-Rom. Pl. Syst. Evol. 259: 249–258.