South African Journal of Botany 89 (2013) 76–84

Contents lists available at ScienceDirect

South African Journal of Botany

journal homepage: www.elsevier.com/locate/sajb

A 2013 linear sequence of legume genera set in a phylogenetic context — A tool for collections management and taxon sampling

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ARTICLE INFO

Available online 25 July 2013

Edited by B-E Van Wyk

Keywords:
Classification
Fabaceae
Leguminosae
List of legume genera
Phylogeny

ABSTRACT

The Leguminosae (or Fabaceae) currently comprises 751 genera. In most of the world's herbaria the genera are arranged by old, non-phylogenetic, classification systems which, while offering insights into morphological similarity, make no explicit statement as to evolutionary relationships. While classifications based on morphology are useful tools for plant identification, they do not offer the predictive value that phylogenetically based linear sequences provide. The legume collection of c.750,000 specimens in the Herbarium of the Royal Botanic Gardens, Kew was moved to a new building between 2010 and 2011, which presented the opportunity to reorganise the collection by a linear sequence based on a number of relatively comprehensive published legume phylogenies. The numbered linear sequence adopted at Kew has been updated and emended to include generic changes that have been published up to March 2013. The linear sequence, together with an alphabetical list of genera, is presented here to serve as a management tool for future taxon sampling and herbarium curation. The process used to develop the linear sequence and to rearrange the legume collection at Kew is discussed together with plans for future dissemination of changes to the sequence as new phylogenies are published and incorporated.

1. Introduction

The Leguminosae (alternative name Fabaceae), commonly called the bean or pea family, is currently divided into three subfamilies (Caesalpinioideae, Mimosoideae and Papilionoideae), further subdivided into 35 tribes which together comprise 751 genera containing a total of c.19,500 species (LPWG, 2013a). The Leguminosae is second only to the grass family in economic value, but has significantly greater habit, flower and fruit diversity. Legumes are ubiquitous throughout the main biomes and occur in nearly all vegetation types globally. Published phylogenies of legumes at the supra-generic level have been accumulating at an ever increasing rate since the beginning of the millennium. An international legume systematics community is now working towards producing a comprehensive phylogenetic estimate and revised classification for all Leguminosae (LPWG, 2013a,b; Wojciechowski, 2013–in this issue).

Many of the world's herbaria are using out-of-date classification systems to arrange plant families and genera. Some have their herbarium specimens ordered alphabetically at all levels of the nomenclatural hierarchy and, whilst convenient for specimen filing and easy consultation, such arrangements are inefficient when used as an identification tool since they carry no predictive value about taxon relationships. Where resources permit, a number of herbaria are now arranging their plant families by the APG system (e.g., the Edinburgh Botanic Garden (E); the Natural History Museum, London (BM), the Muséum National d'Histoire Naturelle, Paris (P), the University of Western Australia (UWA), Duke University, U.S.A. (DUKE), and North Carolina State University, U.S.A. (NCSC)). Many other herbaria are using the APG family delimitation, but order the families alphabetically (E. Haston, pers. comm., and Haston et al., 2007). In the Herbarium of the Royal Botanic Gardens, Kew, Leguminosae (approximately 750,000 specimens) were recently moved (2010–2011) to the newly built fifth wing of the Herbarium building. This presented the opportunity to update the arrangement of the genera from the old Bentham and Hooker (1865) classification to a system that better reflects the modern understanding of inter-generic relationships within legumes. The new arrangement of genera for herbarium specimens was completed in May 2011, and the supplementary legume seed and reprint collections subsequently were rearranged by the same linear sequence. Other large supplementary collections (fruits, illustrations) are in the process of being reorganised according to the new linear arrangement.

Bentham in Bentham and Hooker's (1865) Genera Plantarum recognised 399 genera in the Leguminosae which together comprised c.6500 species. When part 1 of Advances in Legume Systematics (Polhill and Raven, 1981) was published, somewhat before the era of molecular phylogenetics, those numbers had increased to 650 genera and 18,000 species. Thirteen years later (Polhill, 1994), the number of genera recognised had increased to 671, but the estimated number of species had decreased to c.17,000. Legumes of the World (Lewis et al., 2005), an encyclopaedic compendium of legume genera, recognised

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http://dx.doi.org/10.1016/j.sajb.2013.06.005

727 genera and provided a more accurate estimate of 19,325 accepted species in the family. At the time of writing this paper the number of genera stands at 751 and the species at c.19,500 (LPWG, 2013). It is clear from this brief overview that the number of accepted genera and species of legumes has increased significantly in the past 150 years and that the number of accepted genera, even today, is far from static.

Since Legumes of the World (Lewis et al., 2005) a number of genera have been placed in synonymy, e.g., the two monospecific genera *Ophiocarpus* (Bunge) Ikonn. and *Barnebyella* Podlech have been informally returned to *Astragalus* (M.F. Wojciechowski, pers. comm.), *Vaughania* S. Moore has been subsumed back into *Indigofera* (Schrire, 2008), *Spartidium* Pomel becomes a synonym of the reinstated genus *Calobota* Eckl. & Zeyh. (Boatwright et al., 2009); *Pellegriniodendron* (Harms) J. Léonard is now part of *Gilbertiodendron* J. Léonard (Estrella et al., 2012), and *Bergeronia* Micheli and *Margaritolobium* Harms have been reduced to synonyms of *Muellera* L.f. (Silva et al., 2012). The synonymisation of other genera have been proposed (e.g., *Paloveopsis* and *Elizabetha* into *Paloue*, Redden et al., in press; *Guinetia* into *Calliandra*, Souza et al., in press). All native New World species formerly placed in *Lotus* are segregated into four genera: *Hosackia* Douglas ex Lindl., *Acmispon* Raf., *Syrmatium* Vogel and *Ottleya* D.D. Solokoff (Sokoloff, 1999, 2000, 2003; Sokoloff et al., 2007), segregates which we recognise in the linear sequence presented here, although Brouillet (2008) only accepts two: *Acmispon* (including *Syrmatium* and *Ottleya*) and *Hosackia*. Degtjareva et al. (2006, 2008) placed *Dorycnium* Mill. and *Tetragonolobus* Scop. back in synonymy under *Lotus*, and Degtjareva et al. (2012) show that *Anthyllis* is paraphyletic with respect to *Hymenocarpos* Savi, and thus place the latter into synonymy under *Anthyllis*, although these suggested changes are not yet adopted in our list. It is probable that *Securigera* DC. will be placed back into synonymy under *Coronilla* L. (Sokoloff, pers. comm.).

In contrast, since 2005, more than 30 genera have been added to the list of 727 presented in Legumes of the World. A number of generic names have been resurrected from synonymy and are now considered to be accepted genera based on recent phylogenetic analyses: *Phyllolobium* Fisch. (Zhang and Podlech, 2006); *Acaciella* Britton & Rose (Rico Arce and Bachman, 2006): *Senegalia* (Seigler et al., 2006a); *Pityrocarpa* Britton Rose (Jobson and Luckow, 2007); *Vachellia* Wight & Arn. (Brown et al., 2008); *Bionia* Mart. ex Benth. (Queiroz, 2008); *Isomacrolobium* Aubrév. & Pellegr. (Breteler, 2008); *Leptolobium* (Rodrigues and Tozzi, 2008); *Fairchildia* Britton & Rose (Torke and Schaal, 2008); *Calobota* Eckl. & Zeyh. (Boatwright et al., 2009); *Schnella* Raddi (Wunderlin, 2010); *Cochliasanthus* Trew and *Condylostylis* Piper (Delgado-Salinas et al., 2011); *Euchlora* Eckl. & Zeyh., *Listia* E. Mey. and *Leobordea* Del. (Boatwright et al., 2011); *Ototropis* Nees (Ohashi and Ohashi, 2012a); *Steinbachiella* Harms (Lewis et al., 2012). Other taxa have been raised to generic rank from a previously described infrageneric taxon: *Leptospron* (Benth.) A. Delgado, and *Sigmoidotropis* (Piper) A. Delgado (Delgado-Salinas et al., 2011). Some recently recognised segregates have required new generic names: *Guianodendron* Sch. Rodr. & A.M.G.Azevedo (Rodrigues and Tozzi, 2006); *Mariosousa* Seigler & Ebinger (Seigler et al., 2006b); *Wiborgiella* Boatwr. & B.-E. Van Wyk (Boatwright et al., 2009); *Ladeania* A. N. Egan and Reveal (2009); *Ancistrotropis* A. Delgado (Delgado-Salinas et al., 2011); *Ezoloba* B.-E. Van Wyk & Boatwr. (Boatwright et al., 2011); *Helicotropis* A. Delgado (Delgado-Salinas et al., 2011); *Paragoodia* I. Thomps. (Thompson, 2011); and *Verdesmum* Ohashi and Ohashi (2012b). In addition, *Heteroflorum* M. Sousa (2005) and *Tabaroa* L.P. Queiroz, G.P. Lewis & M.F. Wojc. (Queiroz et al., 2010) are newly discovered genera described from relatively recent field-collected specimens. The current estimate of 751 genera and ca. 19,500 species will change soon because more new genera are anticipated (D. Cardoso, A.N. Egan, S.L. Gomez-Acevedo, M. Luckow, J.E. Meireles, H. Ohashi, E.R. Souza, and J.J. Wieringa, pers. comm., and Cardoso et al., 2012b, in which a new genus is flagged, but not formally published), including one described by Mackinder and Wieringa (in press).

The aim of this paper is to provide a generic backbone for the legume family arranged within a phylogenetic context, essentially as a working list of all the legume genera widely accepted in March 2013 by the international legume community. It is hoped that this will serve as a practical guide to taxon sampling in future legume research, as well as a linear sequence by which herbarium curators might choose to arrange their legume genera.

2. Materials and methods

2.1. Collections management

The Leguminosae, together with the Compositae (Asteraceae), were chosen as the two families to be moved to the new building of the Kew Herbarium, officially opened in November 2010. One reason for selecting these two families for the move was to reduce the risk of specimen damage by a number of beetle species, including the biscuit or herbarium beetle (*Stegobium paniceum*) which preferentially seeks out parts of dried specimens (mostly the flowers and fruits) of a number of Compositae and legume genera (particularly the anthers of some taxa, e.g.,members of the Cassiinae) as a food source. The new herbarium building is temperature and humidity controlled and specimens are stored in closed boxes housed on open-shelved compactors in custom-built vaults, all designed to reduce the risk of pest infestation. To minimise the risk of transferring any beetles from the old accommodation to the new building, all specimens were frozen for 72 h at −40 °C prior to their relocation.

To ensure that all legume specimens were moved efficiently, more than 30,000 genus folders were given the appropriate new linear sequence number prior to the material being boxed, frozen and relocated. A detailed spreadsheet was also prepared to cross-map the location of each genus in the old herbarium cupboards with the number of boxes that the genus would occupy in its new location, allowing space for future expansion as newly accessioned material is added to the collection. Between June 2010 and May 2011 an estimated 750,000 legume specimens (including c.30,000 types) were relocated.

To facilitate access to specimens in the new arrangement, each box (holding between c. 25 and c. 100 specimens, depending on individual specimen woodiness) is labelled with genus name and number, species content and geographical region. Coloured stickers indicate the main geographical areas (e.g., Europe, Africa, the Americas) with additional geographical data added as a number that cross references to a standard Kew world list of continental and subcontinental regions. A red stripe was added to the label of a box that contains an index to species, and a blue star indicates the inclusion of cultivated material.

2.2. Enumeration of genera

Due to the increased storage space available in the new building, the move provided an opportunity to reinsert into the legume collection material that, for a number of years, had been stored elsewhere due to lack of space. The move also provided the impetus to rearrange all legume genera by the new linear sequence based on the latest published phylogenies, most of which had already been consulted when preparing genus accounts for Legumes of the World (Lewis et al., 2005). Thus, the linear sequence largely follows the phylogenetic content of Legumes of the World. More specifically, the sequence was adapted from Lewis et al. (2005: 5, Fig. 1: a phylogeny of Leguminoase compiled as a supertree, based on a number of analyses cited therein), and fine-tuned using a series of trees representing the latest view of phylogenetic relationships among genera within each legume tribe