REVIEW ARTICLE

The Apocynaceae TEN (Taxonomic Expert Network)

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Abstract Using the Apocynaceae as an example, the present paper demonstrates how the new tool Rhakhis highlights taxonomic problems in a large vascular plant family and, at the same time, invites specialists in the family to solve these problems with the aim of producing an up-to-date taxonomy. This taxonomy can then be used to estimate species and genus numbers, thus approaching the goal of completing our picture of the diversity surrounding us and providing a solid basis for science and conservation. The most recent estimates for genus and species number in the Apocynaceae are provided.

Keywords Apocynaceae; diversity; nomenclature; taxonomic databases

INTRODUCTION

In a globalized world suffering from rapidly accelerating climate change and biodiversity loss, thorough knowledge of plants, their diversity, ecology, morphological and chemical properties is more important than ever. All this information is tied to the name of a species. For this reason, it is essential that plant names are applied correctly and consistently, and that nomenclatural changes necessary as results of new (phylogenetic) studies, are incorporated in the existing framework quickly and consistently. A comparison between the most popular summary taxonomic checklists has shown that the information displayed is only to 60% identical between these checklists; a test on an expert-curated checklist in Meliaceae (a family of just about 600 species) resulted in a similarly low percentage of coincidence (Schellenberger Costa & al., 2023). In large angiosperm families, of course, these problems are particularly pronounced, and in some, attempts have started early to arrive at a consensus classification and nomenclature by collaborative efforts, e.g., the Legume Phylogeny Working Group (LPWG, 2013) and the Compositae Working Group (CWG, 2024). However, such active networks are rather the exception than the rule, and smaller networks often become inactive when the driving individual(s) retire or change interests. Even if their work is then still available online, it can no longer be updated easily (e.g., Gentian Research Network, Struwe, 2002–2019). World Flora Online (WFO, 2024), founded in 2012, the international initiative to provide a global overview of the diversity of plant species, is a platform to integrate these efforts and provide an up-to-date classification of plants, with the aim to include all effectively published plant names, and make them retrievable with a unique WFO identifier, regardless of its taxonomic and nomenclatural status. From this taxonomic backbone, a single classification of taxon names and their synonyms can be built, to which descriptions, images, geographic distribution and other information can be added. The information is provided by Taxonomic Expert Networks (TENs; Borsch & al., 2020). A current list of TENs – and also a list of families still missing a TEN – is provided online (https://about.worldfloraonline.org/tens).

Only two years ago, the Rhakhis tool, a data management system, was released (Hyam & al., 2022), with the aim to maintain taxonomy for the WFO. With this system, it is now possible for members of a TEN to directly edit taxonomic information online, such as correcting literature citations and synonymies, something that is difficult in other databases, where it usually at least needs an email to the database provider, who integrates this information – or not. With such a tool at the fingertips, there is now the chance to produce an updated taxonomic backbone for Apocynaceae Juss., a family that in the last 30 years has seen large advances in the understanding of species composition and phylogenetic relationships (e.g., Bitencourt & al., 2021).

APOCYNACEAE IN NUMBERS

Apocynaceae, the dogbane family, is one of the 10 to 12 largest angiosperm families, comprising at the last count (Endress & al., 2018) 378 genera and approximately 5290 species. The division of the family into grades and subfamilies, as well as the division of these entities into tribes as outlined in Endress & al. (2018), has stood the test of almost all

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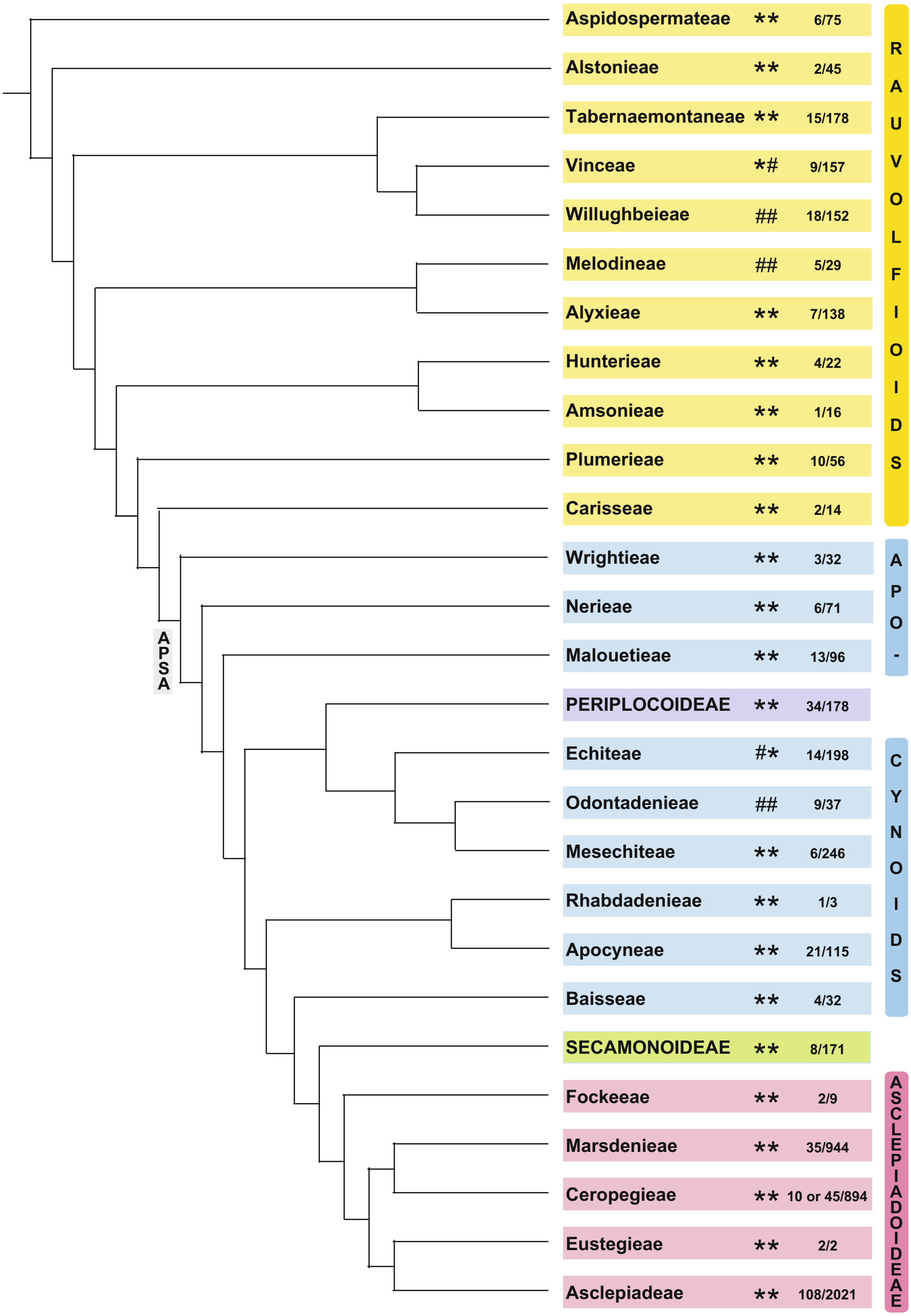

Fig. 1. Summary tree of Apocynaceae, adapted from Cole (2019), changed to include results of Wang & al. (2023). * monophyletic group; # non-monophyletic group. First symbol according to Fishbein & al. (2018), second symbol according to Wang & al. (2023). Numbers indicate genera/species, corresponding to Table 1. APSA denotes the crown clade of Apocynaceae, comprising Apocynoids, Periplocoideae, Secamonoideae, and Asclepiadoideae.

recent studies (Fig. 1, Table 1). Nevertheless, since Endress & al. (2018), roughly 460 species have been newly described, about 390 in Asclepiadoideae alone (International Plant Names Index; IPNI, 2024). Taxonomic concepts inside some higher divisions are not yet so stable. In Apocynoids, phylogenetic study has led to some generic rearrangement between the subtribes of Apocyneae (Livshultz & al., 2018); it is likely that other Apocynoid (and possibly also Rauvolfioid) tribes will see similar rearrangements after phylogenetic study, as indicated by the non-monophyletic retrieval of several Rauvolfioid and Apocynoid tribes (Fig. 1). In Periplocoideae, the circumscription of some genera is still not clear (compare, e.g., Sidney, 2012, and Rodda, 2020), and also the position of Periplocoideae inside the Apocynoid grade, first suggested by Livshultz & al. (2007) and supported by Wang & al. (2023), but not by Fishbein & al. (2018), has not yet been finally clarified. In Secamonoideae, the status of *Genianthus* Hook.f. and *Toxocarpus* Wight & Arn. as synonyms of

Table 1. Genera and species numbers in the Apocynaceae (as of 31 December 2023).

Higher division	Tribe	Subtribe	Number of genera	Number of monotypic genera	Number of species
Rauvolfioids	Aspidospermateae		6	1	75 (69)
	Alstonieae		2		45
	Vinceae	Kopsiinae	1		24 (23)
		Ochrosiinae	1		40
		Tonduziinae	2		7
		Vincinae	1		7
		Catharanthinae	3		19
		Rauvolfiinae	1		60
	Willughbeieae	Leuconotidinae	3	1	7
		Willughbeiinae	1		16
		Landolphiinae	10	3	92 (85)
		Lacmelleinae	4		37
	Tabernaemontaneae	Ambelaniinae	7	1	20
		Tabernaemontaninae	8	3	158 (148)
	Amsonieae		1		16
	Melodineae		5	4	29
	Hunterieae		4	1	22 (20)
	Alyxieae	Condylocarpinae	3		24
		Alyxiinae	4		114
	Plumerieae	Allamandinae	1		15 (14)
		Plumeriinae	3	1	17
		Thevetiinae	6	1	24
	Carisseae		2		14 (13)
Apocynoids	Wrightieae		3	1	32 (31)
	Nerieae	Neriinae	2	1	6
		Alafiinae	4	1	65
	Malouetieae	Galactophorinae	1		6
		Pachypodiinae	2		26 (25)
		Malouetiinae	10	4	64
	Rhabdadenieae		1		3
	Odontadenieae		9	4	37 (36)
	Mesechiteae		6	1	246 (233)
	Echiteae	Laubertiinae	2		6
		Peltastinae	3		20
		Echitinae	5		25
		Parsonsiinae	3	1	87
		Prestoniinae	1		60 (58)
	Apocyneae	Papuechitinae	3	2	19
		Amphineuriinae	2 (3)	2 (3)	2 (3)
		Beaumontiinae	3	1	14

(Continues)

Table 1. Continued.

Higher division	Tribe	Subtribe	Number of genera	Number of monotypic genera	Number of species
	Apocyneae *(continued)*	Apocyninae	2		11
		Urceolinae	2 (1)	1 (0)	21 (20)
		Chonemorphinae	4	1	29
		Ichnocarpinae	4 (5)	0 (1)	18 (19)
		Unplaced	1 (0)	1	1
	Baisseae		4	1	32 (29)
Periplocoideae			34 (33)	8	178 (176)
Secamonoideae			8	1	171 (158)
Asclepiadoideae	Fockeeae		2		9
	Marsdenieae		35 (26)	14 (12)	944 (738)
	Ceropegieae	Heterostemminae	1		37 (30)
		Anisotominae	5		32 (30)
		Leptadeniinae	3 (4)	1	15 (17)
		Stapeliinae	36 or 1	8 or 0	810 (722)
	Eustegieae		2	2	2
	Asclepiadeae	Astephaninae	3	1	15
		Asclepiadinae	26	4	342 (335)
		Cynanchinae	2		259 (252)
		Tylophorinae	2		172 (154)
		Pentacyphinae	1		3
		Diplolepinae	1		14
		Orthosiinae	4		143 (102)
		Metastelmatinae	12	2	297 (289)
		Tassadiinae	1		35
		Oxypetalinae	6		216 (207)
		Gonolobinae	48 (45)	24 (21)	522 (412)
		Topeinae	1		2
		Unplaced	1	1	1

For ease of calculation, ranges of species numbers have been reduced to the median, and "ca." has been omitted, as in almost all groups there is some uncertainty as to the number of species that grows with the size of the group. Numbers in parentheses correspond to the numbers given by Endress & al. (2018); genera and species published since then have been obtained via IPNI (consulted 20 January 2024). The arrangement of tribes and subtribes follows Endress & al. (2018). **Bold** indicates taxa with substantial rearrangements since Endress & al. (2018) or diverging taxonomic concepts, discussed in the text.

Secamone R.Br., proposed by Klackenberg (2001, 2004) and Rodda & al. (2024) is still lacking phylogenetic confirmation. In Asclepiadoideae, major reorganization following phylogenetic study has taken place in Marsdenieae, increasing the number of accepted genera from 26 to 35, both by resurrection of synonyms and by description of new genera (Liede-Schumann & al., 2022). While the *Hoya* R.Br. alliance was explicitly not subject of Liede-Schumann & al. (2022), ongoing studies might lead to further shifts in generic circumscription (e.g., Rodda & al., 2020). A similar process is still ongoing in Gonolobinae (Asclepiadoideae-Asclepiadeae), mainly by Morillo (2012, 2013, 2015, 2023a,b), increasing the number of genera to date by three. In both Marsdenieae and Gonolobinae, the intensified study has as well led to a considerable increase of species (more than 200 in Marsdenieae, 110 in Gonolobinae). Generic boundaries are also still ill-defined in other larger Asclepiadeae subtribes, e.g., Metastelmatinae (see, e.g., Silva & al., 2012) and Old World Asclepiadinae (Chuba & al., 2017), so that any modern phylogenetic reassessment will probably lead to massive changes in generic circumscriptions. This has happened lately in Cynanchinae (Khanum & al., 2016) and Tylophorinae

(Liede-Schumann & al., 2012, 2016; Liede-Schumann & Meve, 2018), leading to a massive reduction to only two genera in either subtribe. In Stapeliinae, phylogenetic study has likewise triggered a major decrease in genus number, from 36 genera to 1 genus, *Ceropegia* L., advocated by Bruyns & al. (2017). However, morphological discordance in this super-genus is such that other researchers prefer to separate the stem-succulent stapeliads from *Ceropegia*, acknowledging that *Ceropegia* without the stapeliads is a paraphyletic genus (e.g., Meve & Liede-Schumann, 2007). Fortunately, this controversy is the only major one in the family; smaller ones concern, e.g., the split of *Seutera* Rchb. from *Funastrum* E.Fourn. (Fishbein & Stevens, 2005, not followed by Endress & al., 2018), the inclusion of *Morrenia* Lindl. in *Araujia* Brot. (Rapini & al., 2011, not followed by Endress & al., 2018), the inclusion of *Parquetina* Baill. in *Cryptolepis* R.Br. (Joubert & al., 2016, not followed by Endress & al., 2018), and the recent inclusion of *Orthanthera* Wight in *Leptadenia* R.Br. (Bruyns & al., 2023). The newest figures, obtained for the present paper, indicate 392 genera and 5747 species in the Apocynaceae. Throughout all groups, the number of mono- and bitypic genera is high, reaching a total of 40%.

Table 2. Comparison of genus and species numbers in some frequently used taxonomic sources, and three examples of discordance (see text).

	Accepted genera	Accepted taxa	References (all accessed 22 Apr 2024)	*Gongreos*	*Meveampelos*	*Metastelma chiapense*
CoL	347	6616 spp.; 583 infraspecific taxa	Costello & al., 2022. Two million species catalogued by 500 experts. *Nature* 601 (7892): 191. doi.org/10.1038/d41586-022-00010-z; www.catalogueoflife.org/data/taxon/6L2	Yes: 2 spp.	Yes: 2 spp.	*M. arizonicum* subsp. *chiapense* (A.Gray) Liede & Meve
GBIF Backbone	409	7194 spp.	GBIF Secretariat: GBIF Backbone Taxonomy. doi.org/10.15468/39omei, accessed via www.gbif.org/species/6701	Yes: 2 spp.	No	*M. arizonicum* subsp. *chiapense* (A.Gray) Liede & Meve
LCVP	307	5273 spp.; 379 infraspecific taxa	Freiberg, M. & al. 2020. LCVP, The Leipzig catalogue of vascular plants, a new taxonomic reference list for all known vascular plants. *Sci. Data* 7: 416. doi.org/10.1038/s41597-020-00702-z	Yes: 2 spp.	No	*M. arizonicum* subsp. *chiapense* (A.Gray) Liede & Meve
POWO	388	6650 spp.; 655 infraspecific taxa	Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. www.plantsoftheworldonline.org/, accessed via powo.science.kew.org/results?q=apocynaceae	Yes: 2 spp.	Yes: 2 spp.	Yes
Tropicos				Yes: 2 spp.	No	*Cynanchum chiapense* (A.Gray) Standl. & Steyerm. *M. arizonicum* subsp. *chiapense* (A.Gray) Liede & Meve
WCVP via GBIF	380	7565 spp.	Apocynaceae. In: Govaerts, R. 2023. The World Checklist of Vascular Plants (WCVP). Royal Botanic Gardens, Kew. Checklist dataset. doi.org/10.15468/6h8ucr, accessed via GBIF.org	Yes: 2 spp.	No	Yes
WP	347	6627 spp.	Hassler, M. 1994–2024. World Plants: Synonymic Checklist and Distribution of the World Flora. Version 19.2. www.worldplants.de	Yes: 4 spp.	Yes: 2 spp.	*M. arizonicum* subsp. *chiapense* (A.Gray) Liede & Meve
WFO	384	6418 spp.; 556 infraspecific taxa	wfoplantlist.org/taxon/wfo-7000000038-2023-12	Yes: 4 spp.	Yes: 2 spp.	Yes

Gongreos Rodda, Liede & Meve in Taxon 71(4): 850. 2022; *Meveampelos* Morillo in Mem. Fund. La Salle Ci. Nat. 81(191): 57. 2023; *Metastelma chiapense* A.Gray in Proc. Amer. Acad. Arts 21(2): 397. 1886, reinstated by Liede-Schumann & al. in Syst. Bot. 39: 606. 2014

■ APOCYNACEAE IN WFO AND RHAKHIS

Comparing seven generally used taxonomic databases (Table 2) yields diverging results both in summary figures and in integration of more recent taxonomic changes. IPNI is not considered here because it gives no taxonomic opinion. The number of accepted genera in the Apocynaceae ranges from 307 to 409, with 5273 to 7565 accepted species. Each database is specific about the data reported – some list infraspecific taxa, synonyms, doubtful names or other additional information. For Tropicos (2024) it is not possible to generate a summary statistic for a family.

In terms of classification, none of these sources is up to date, as three random examples from Apocynaceae demonstrate. All sources report the new genus *Gongreos* Rodda & al., published in *Taxon* (2022). But only World Plants (WP, Hassler, 1994–2024) has caught the two additional species published by Rodda in *Thai Forest Bulletin (Botany)* in 2024. *Meveampelos* Morillo, published in *Memoria de la Fundación La Salle de Ciencias Naturales* (2023), is listed only in three of the seven databases. While time will probably add these names to the remaining sources, the much older reinstatement of *Metastelma chiapense* A.Gray by Liede-Schumann & al. (2014) is reflected only by World Checklist of Vascular Plants (WCVP) and Plants of the World Online (POWO), while the other sources list it as subspecies of *M. arizonicum* A.Gray, still following Liede & Meve (2004). While some specialists take considerable trouble to send changes and point out errors and novelties to the database managers, this task is impossible to complete for a whole family. The approach of WFO to assign specialist curators to families and genera, therefore, might be the most efficient way to streamline our knowledge on vascular plants and to provide reliable data for other researchers, conservationists, politicians and the general public.

The new Rhakhis tool (Hyam & al., 2022; for details on terminology and concepts, see https://github.com/rogerhyam/wfo-plant-list-docs/blob/main/docs/concepts.md), designed to build and maintain a working checklist of the world's plants (WFO Plant List) by implementing a subset of rules of the *International Code of Nomenclature for algae, fungi, and plants* (*ICN*, Turland & al., 2018), is a milestone in facilitating the task of keeping the taxonomy of a plant family up to date. Updating a name is simple and almost self-explanatory – of course, to look up the necessary taxonomic information can still be cumbersome. After login with the ORCID (Open Researcher and Contributor ID; Shillum & al., 2021), the curator of a family can nominate other editors for the whole family or a number of genera. So far, it is not possible to assign subdivisions of a family, such as subfamilies or tribes with one click; this works only by selecting the appropriate genera. A selection of taxa by region is also not possible. A curator can edit the taxon, any descendent taxa and any synonyms of these taxa.

A taxon can either be searched directly by name ("matching"), or found by scrolling the species under a genus ("browsing"), or is retrieved from the list of "unplaced names" under a genus or the family. Following POWO (https://powo.science.kew.org/about, accessed 20 Jan 2024), "unplaced names are names that cannot be accepted, nor can they be put into synonymy. This may be because the name is not validly published, or it is a later homonym and therefore illegitimate or because the genus name is not accepted. A name can also be unplaced because it cannot be put into synonymy which may be because no correct name is available in an accepted genus, this may also be because no type material is known to exist and therefore it cannot be established to which species concept the name belongs or the type material may be insufficient to establish a clear identity or it may not have been studied by experts in the group and therefore no published synonymy exists." So far, in many cases, an "unplaced name" has been listed in this category without good reason and is easily attributed to a known species, but obscure and poorly documented names are also found here.

Figure 2 shows a typical Rhakhis editing page for an accepted species. An editor can edit the nomenclatural status, the author string, the publication, the nomenclatural references, and the comments (left column). Then, in the right column, the placement of the taxon, the hybrid status and the basionym can be changed. However, to place a species in synonymy requires that all the names listed as synonyms of this name must first be placed in the synonymy of the new accepted species. Likewise, to move a genus to synonymy, all species under it have to be moved first. Both can be cumbersome if there are many synonyms or species.

Beyond clarifying taxonomic issues, it would be desirable to add higher classification ranks (subfamilies, tribes and subtribes), not only to ease attribution of such a unit to a particular editor, but also to facilitate comparative studies comprising larger entities by easily building the appropriate checklists. Apart from these possible future expansions aimed at facilitating the use of the data, this platform offers the unique opportunity to create and maintain an up-to-date state of taxonomy and to either attribute old "skeletons in the closet" to recent, accepted species – or finally bury them for good. Once this work is done, it will be easy to retrieve genus and species numbers for a family and rank angiosperm families by species number to obtain a much improved picture of global plant diversity.

■ THE APOCYNACEAE TEN

Having worked in Apocynaceae since 1989, I volunteered to lead the TEN for Apocynaceae. In the meantime, several other well-known specialists have signed up (alphabetically): Héctor A. Keller (National University of the Northeast, Corrientes, Argentina), focussing on Argentinian Asclepiadoideae; Ulrich Meve (University of Bayreuth, Germany), focussing on Ceropegieae and Fockeeae; J. Francisco Morales

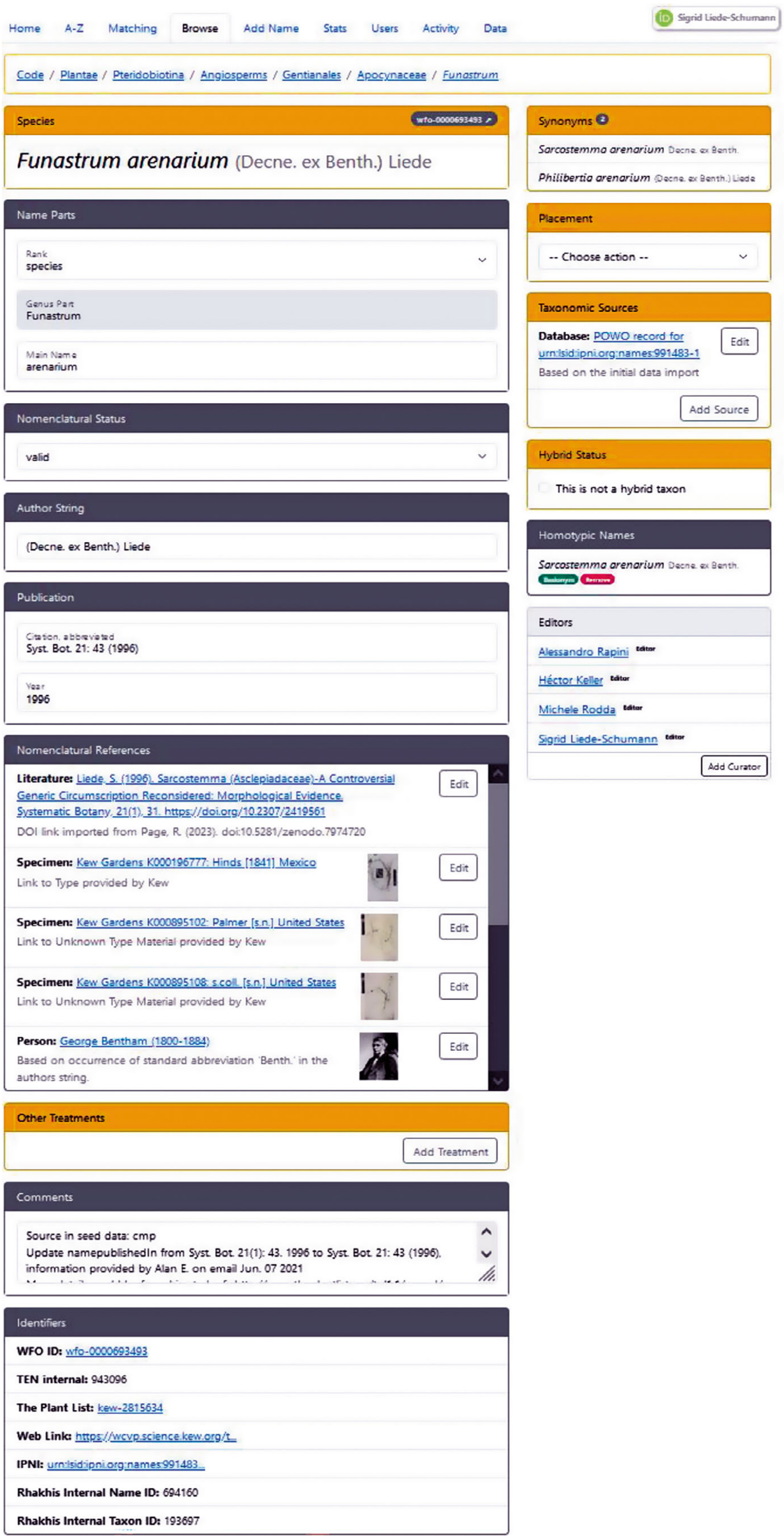

Fig. 2. Screenshot of an editing page in Rhakhis.

Version of Record

(National Herbarium of Trinidad and Tobago), focussing on non-asclepiadoid Apocynaceae of the Americas; Alessandro Rapini (Universidade Estadual de Feira de Santana, Brazil), focussing on the Asclepiadoideae of Brazil; and Michele Rodda (Singapore Botanic Gardens), with emphasis on southeast Asian taxa and the *Hoya*-alliance. We still encourage taxonomically well-versed colleagues to join us – especially for underrepresented regions such as Africa and the Pacific, and underrepresented groups such as paleotropical Rauvolfioids, Periplocoideae and Secamonoideae. So far, we are just a small working group with members who have known each other for many years, so communication is both open and informal. Should the group grow and irreconcilable differences surface, a more standardized approach might be necessary. The methods to solve the taxonomic chaos vary between people – the scientific approach to tackle a whole genus and check names and synonymy one by one is certainly the royal road to a perfect nomenclature, but also the most time-consuming one. For those who enjoy nomenclatural problems, it is also possible to select one or a few problematic taxa and clarify their status, reducing the number of "unplaced names" and sometimes finding new, unexpected insights in familiar groups. With all the issues and uncertainties, we nevertheless hope to complete the task within reasonable time – the addictive qualities of Rhakhis should not be underestimated!

When we started working in November 2023, the external view "classification snapshot" of June 2023 indicated 7307 accepted names at all ranks, 6369 accepted species, 1711 unplaced species and 380 accepted genera (https://wfoplantlist.org/plant-list/taxon/wfo-7000000038-2023-06, accessed 20 Dec 2023). The editing statistics "stats" in Rhakhis (https://list.worldfloraonline.org/rhakhis/ui/#stats, accessed 20 Dec 2023) showed even larger gaps in our knowledge, with 7349 taxa, 3421 unplaced taxa, 506 unplaced species names with occurrences in the Global Biodiversity Information Facility (GBIF) and 18,390 occurrence records in GBIF tagged with unplaced species names. Asclepiadaceae is correctly given as a synonym of Apocynaceae in both views, but the editing statistics still shows 6 genera and 179 species under Asclepiadaceae. Of course, old "dustbin genera" such as *Hoya* (148 unplaced names), *Cynanchum* L. (80 unplaced names) and *Asclepias* L. (68 unplaced names, all on 20 Dec 2023), which are often taxonomically difficult, will require considerable efforts to resolve. The first months of our activity improved the above figures – but only slightly. So, presently we stand at 7359 accepted names at all ranks, 6418 accepted species, 556 infraspecific taxa, 1555 unplaced species and 384 accepted genera (https://wfoplantlist.org/taxon/wfo-7000000038-2023-12, accessed 24 Apr 2024).

AUTHOR CONTRIBUTIONS

I wrote this paper entirely myself, using none than the references indicated.

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