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Changes in the circumscription of the genus *Achillea* (*Compositae-Anthemideae*) and its subdivision**Abstract**

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On the basis of recent multidisciplinary (including DNA-analytical) studies, the fusion of the genera *Otanthus* and *Leucocyclus* with *Achillea* is proposed. A taxonomic and nomenclatural survey of the genus includes amendments in the circumscription of all accepted sections and new combinations for *A. sect. Otanthus*, *A. maritima*, *A. maritima* subsp. *atlantica* and *A. formosa* subsp. *amanica*.

This comment on the taxonomy of *Achillea* is based on results from recent multidisciplinary (including DNA-analytical) studies on the genus, already published (Guo 2004, Guo & al. 2004, Guo & al. 2005a) or submitted (Guo & al. 2005b, Ehrendorfer & Guo 2005). A contribution on the genus in Bulgaria (Saukel & al. 2004) and an earlier taxonomic survey of the genus by Klokov & Krytzka (1984) are also relevant. Furthermore, it is of importance that the long-lasting dispute about the type of the name *Achillea* is now settled. In accordance with Art.10.5b of the Code (Greuter & al. 2000), the earlier type designation (*A. santolina* L., chosen by Britton & Brown 1913, under the American Code; see also Valant-Vetschera 1996) has to be replaced by *A. millefolium* L. as generic type (following Green in Hitchcock & Green 1929; see also <http://internet.nhm.ac.uk/cgi-bin/botany/linnaean/detail.dsm1?ID=3600>). As a consequence, what was formerly *A. sect. Achillea* (e.g., in Klokov & Krytzka 1984), is now *A. sect. Santolinoideae* (DC.) Heimerl, whereas the former *A. sect. Millefolium* (Mill.) W. D. J. Koch now becomes *A. sect. Achillea*. Altogether, the present comments supplement Euro-Med Notulae No. 1 on the *Compositae-Anthemideae* (Greuter & al. 2003).

On the basis of a cladistic analysis, Bremer & Humphries (1993) and Bremer (1994) have placed *Achillea* into the new subtribe *Achilleinae*, together with *Anacyclus*, *Chamaemelum*, *Cladanthus*, *Leucocyclus*, *Mecomischus*, *Otanthus*, *Rhetinolepis* and *Santolina*. Subsequent DNA sequence data on generic relationships within *Anthemideae* by Watson & al. (2000, on plastid *ndhF*), by

Oberprieler & Vogt (2000, on nrITS and plastid *trnL-F*), Francisco-Ortega & al. (2001, on nrITS) and Oberprieler (2002 and 2004, on nrITS and plastid *trnL-F*) have shown that closer genetic affinities only exist between *Achillea*, *Anacyclus*, *Leucocyclus* and *Otanthus* as core genera of what is now called *Achilleinae* I, but not with the other genera, originally included in the subtribe and now mostly delegated to *Achilleinae* II (Oberprieler 2002). In addition, unsuspected affinities of *Achillea* with *Tanacetum*, *Anthemis* and even *Matricaria* and *Tripleurospermum*, placed into other subtribes by Bremer & Humphries (1993) and Bremer (1994), have created further uncertainties about the delimitation of *Achilleinae* I.

Our own DNA-analytical studies were based on a much larger number of taxa (about 500 individuals, 70 taxa, cytotypes and hybrids) and have used nuclear (nrITS) and plastid (*trnL-F*) DNA sequences, AFLP fingerprinting and plastid haplotype analyses. They support the former studies with respect to limiting the core of *Achilleinae* to *Achillea* (centred in the E Mediterranean and SW Asia) and its sister genus *Anacyclus* (centred in the W Mediterranean). Furthermore, they clarify the relationships between *Otanthus*, *Leucocyclus* and *Achillea*, and suggest possibilities for the subdivision of the latter genus.

Relevant trees based on our DNA sequences should be consulted in an earlier (Guo & al. 2004) and a more extended version (Guo 2004, Ehrendorfer & Guo 2005). Both versions demonstrate basal clades of *Achillea* with *Otanthus maritimus* and *A. sect. Babounya: A. fragrantissima*, *A. sect. Santolinoideae: A. cretica* L., *A. teretifolia* Willd., *A. santolinoideae* Lag. (= *A. wilhelmsii* C. Koch) and representatives of *A. sect. Ptarmica*. In the extended version additional taxa have been considered: *Leucocyclus formosus*, *A. sect. Arthrolepis: A. membranacea* and *A. sect. Santolinoideae: A. pseudoaleppica* Hub.-Mor., *A. teretifolia* Willd. and *A. vermicularis* Trin. In both versions one finds strict consensus trees and parsimony trees with branch length reflecting genetic distance, both for nrITS and for plastid *trnL-F*. All these trees exhibit a comparable topology and support the following conclusions: (1) *Otanthus* and *Leucocyclus* are always interspersed and clearly linked with different members of the *Achillea* sections *Babounya*, *Arthrolepis* and *Santolinoideae*. (2) *Otanthus* exhibits no closer affinity with *Leucocyclus*, appears slightly more isolated, particularly in the plastid sequences, and tends to be located on longer branches. (3) No recurrent pattern of affinities and subclades can be recognized in this assembly of taxa, which are here combined as *A. sect. Babounya* s. lat. (4) This assembly is linked by somewhat aberrant Caucasian members of *A. sect. Ptarmica* (*A. ptarmicifolia* (Willd.) Rupr. and *A. biserrata* M. Bieb.) to the core group of the section with *A. ptarmica* L., *A. acuminata* (Ledeb.) Sch. Bip., *A. salicifolia* Bess., *A. impatiens* L., etc. (5) *A. sect. Babounya* s. lat. and *A. sect. Ptarmica* s. str. together form the basal branches in the genus and are well separated from the remaining sections.

A morphological comparison also shows that the differential characters of *Otanthus* and *Leucocyclus* against *Achillea* do not really hold up. In *Otanthus*, leaf shape and lack of female ray flowers are comparable to *A. fragrantissima*; only the spongy corolla appendages adherent to the achenes are more strongly developed in *Otanthus*. Thus, our first taxonomic proposal is to unite *Otanthus* with *Achillea*, but to create a separate section and new combination for its only species:

Achillea sect. *Otanthus* (Hoffmanns. & Link) Ehrend. & Y.-P. Guo, **comb. & stat. nov.** ≡ *Otanthus* Hoffmanns. & Link, Fl. Portug. 2: 364. 1834? ≡ *Diotis* Desf., Fl. Atl. 2: 261. 1798, nom. illeg., non Schreb. (1791). – Type: *Achillea maritima* (L.) Ehrend. & Y.-P. Guo, **comb. nov.** ≡ *Filago maritima* L., Sp. Pl.: 927. 1753 ≡ *Athanasia maritima* (L.) L., Sp. Pl., ed. 2: 1182. 1763 ≡ *Diotis candidissimus* Desf., Fl. Atl. 2: 261. 1799, nom. illeg. (superfl.) ≡ *Diotis maritima* (L.) Desf. ex Cass. in Dict. Sci. Nat. 13: 295. 1819 ≡ *Otanthus maritimus* (L.) Hoffmanns. & Link, Fl. Portug. 2: 364. 1834?

Two subspecies of *Achillea maritima* can be recognized:

Achillea maritima subsp. *maritima* (≡ *Otanthus maritimus* subsp. *maritimus*) and *Achillea maritima* subsp. *atlantica* (Chrtek & B. Slavík) Ehrend. & Y.-P. Guo, **comb. nov.** ≡ *Otanthus maritimus* subsp. *atlanticus* Chrtek & B. Slavík in Fl. Medit. 3: 244. 1993.

Our second taxonomic proposal is to unite *Leucocyclus* with *Achillea*. Again, the assumed generic difference related to the margins of the outer disc achenes is of a very gradual nature: compressed into wings in *Leucocyclus* and into ribs in *Achillea*. In their detailed morphological analysis of *A.* sect. *Santolinoideae*, Valant-Vetschera & Kästner (2000) have stressed the lack of general differences in the characteristic leaf structures shared with *Leucocyclus* and *A.* sect. *Arthrolepis*. On the basis of nrDNA ITS sequences Oberprieler (2004) has critically discussed the close relationship between *Achillea* and *Leucocyclus*. Our own DNA-analytical evidence (Guo 2004, Ehrendorfer & Guo 2005) clearly shows that *Leucocyclus* forms part of an assembly with the *Achillea* sections *Babounya*, *Arthrolepis* and *Santolinoideae*. Thus, *Leucocyclus* apparently does not merit a separate infrageneric rank. For the whole assembly we provisionally accept the oldest available name on the level of section, use it in a wide sense and provide proper combinations for the former *Leucocyclus* taxa:

Achillea sect. ***Babounya*** (DC.) O. Hoffm., Nat. Pflanzenfam. 4, 5: 273. 1894, s. lat. \equiv *Santolina* sect. *Babounya* DC., Prodr. 6: 36. 1838. – Type: *Santolina fragrantissima* Forssk., Fl. Aegypt.-Arab.: 147. 1775 \equiv *Achillea fragrantissima* (Forssk.) Sch. Bip. in Flora (Regensb.) 38: 13. 1855. = *Leucocyclus* Boiss., Diagn. Pl. Orient., ser. 1, 11: 13. 1849. – Type: *Leucocyclus formosus* Boiss., l.c. 14. 1849.
 = *Arthrolepis* Boiss., Diagn. Pl. Orient., ser. 1, 11: 14. 1849 \equiv *Achillea* sect. *Arthrolepis* (Boiss.) Boiss., Fl. Orient. 3: 255. 1875. – Type: *Anthemis membranacea* Labill., Icon. Pl. Syr. 3: 14, t. 9. 1809 \equiv *Achillea membranacea* (Labill.) DC., Prodr. 6: 32. 1838 \equiv *Arthrolepis membranacea* (Labill.) Boiss., Diagn. Pl. Orient., ser. 1, 11: 15. 1849.
 = *Achillea* [unranked] *Santolinoideae* DC., Prodr. 6: 30. 1838 \equiv *Achillea* sect. *Santolinoideae* (DC.) Heimerl in Denkschr. Kaiserl. Akad. Wiss. Wien, Math.-Naturwiss. Kl. 48: 115. 1875. – Type: *Achillea santolinoides* Lag., Gen. Sp. Nov.: 30. 1816.¹
 = *Achillea* sect. *Aleppicae* Klok. & Krytzka in Ukrains'k. Bot. Žurn. 43(3): 9. 1984. – Type: *Achillea aleppica* L.
 = *Achillea* sect. *Creticae* Klok. & Krytzka, l.c. 9. – Type: *Achillea cretica* L.

Achillea formosa (Boiss.) Sch. Bip. in Flora (Regensb.) 38: 13. 1855 \equiv *Leucocyclus formosus* Boiss., Diagn. Pl. Orient., ser. 1, 11: 14. 1849.

Achillea formosa includes two subspecies, subsp. *formosa* and subsp. *amanica* (Rech. f.) Ehrend. & Y.-P. Guo, **comb. nov.** \equiv *Achillea amanica* Rech. f. in Ark. Bot., ser. 2, 5(1): 442. 1959 \equiv *Leucocyclus formosus* subsp. *amanicus* (Rech. f.) Hub.-Mor. & Grierson in Notes Roy. Bot. Gard. Edinburgh 33: 432. 1975.

After the inclusion of *Otanthus* and *Leucocyclus*, the genus *Achillea* corresponds to an obviously monophyletic clade. This clearly contradicts the efforts by Klokov & Krytzka (1984), Sytnik & Androshchuk (1984) and others to revive the generic separation of *Ptarmica* Mill. from *Achillea* L., which had been maintained by Candolle (1838: 19-24). Additional recent evidence against such a separation comes from the demonstration of an allotetraploid bridge between *A.* sect. *Ptarmica* [*A. acuminata* (Ledeb.) Sch. Bip.] and *A.* sect. *Achillea* [*A. asiatica* Serg.] (Guo & al. 2005a, b, Ehrendorfer & Guo 2005).

Since the early 19th century it has become customary to circumscribe the heterogeneous *Achillea* sect. *Ptarmica* in a very wide sense, to incorporate all taxa outside of *A.* sect. *Babounya* s. lat. with more numerous ligulate flowers in relatively large flower heads arranged in few- (or even single-) headed synflorescences. Already Candolle (1838) had proposed to subdivide the genus *Ptarmica* into three unranked groups, i.e. *Anthemoideae*, *Pectinatae* and *Euptarmicae*. This sub-

¹ Even if Candolle (1838) does not indicate a type, according to the Code Art. 22.6 (Greuter & al. 2000), a typification of *A.* sect. *Santolinoideae* with *A. santolinoides* Lag. is obligatory. The fact that Klokov & Krytzka (1984) propose *A. santolina* L. as lectotype for the section is irrelevant.

division was elaborated by Heimerl (1884), who separated under *A.* sect. *Ptarmica* on the one hand *A.* sect. *Anthemoideae* and sect. *Montanae* for taxa centred in the high mountain systems of Central and S Europe and on the other hand *A.* sect. *Euptarmicae* for northern hemisphere taxa, predominantly from humid localities at lower elevations. In the light of available DNA-analytical and other evidence this subdivision is justified as Heimerl's *Achillea* sections *Euptarmicae* and *Anthemoideae* + *Montanae* are well separated, the former linked with *A.* sect. *Babounya* s. lat., the latter with *A.* sect. *Achillea* s. lat. Nevertheless, a nomenclatural problem remains: Heimerl (1884) was inconsistent in using the rank of section both at a higher (*Achillea* sect. *Ptarmica*) and at a lower level (*Achillea* sect. *Euptarmicae*, sect. *Anthemoideae*, sect. *Montanae*: not subsections as indicated in Klokov & Krytzka 1984!). In spite of this, Heimerl's names are valid according to the ICBN (Greuter & al. 2000). The taxonomic and nomenclatural consequences of these findings are outlined below:

Achillea sect. ***Ptarmica*** (Mill.) W. D. J. Koch, Syn. Fl. Germ. Helv.: 370. 1837, s. str. \equiv *Ptarmica* Mill., Gard. Dict., abridged ed. 4: 1130. 1754 \equiv *Ptarmica* [unranked] *Euptarmicae* DC., Prodr. 6: 22. 1838 \equiv *Achillea* sect. *Euptarmicae* (DC.) Heimerl in Denkschr. Kaiserl. Akad. Wiss. Wien, Math.-Naturwiss. Kl. 48: 132. 1884. – Type: *Achillea ptarmica* L. \equiv *Ptarmica vulgaris* DC.
 \equiv *Ptarmica* sect. *Biserratae* Klok. & Krytzka in Ukrains'k. Bot. Žurn. 41(3): 1-2. 1984. – Type: *Ptarmica biserrata* (M. Bieb.) DC. \equiv *Achillea biserrata* M. Bieb.
 \equiv *Ptarmica* sect. *Pectinatae* (DC.) Klok. & Krytzka, l.c. 2, p.p. – Type: *Ptarmica alpina* (L.) DC. \equiv *Achillea alpina* L.

Achillea sect. ***Anthemoideae*** (DC.) Heimerl in Denkschr. Kaiserl. Akad. Wiss. Wien, Math.-Naturwiss. Kl. 48: 131, 133. 1884, s. lat. \equiv *Ptarmica* [unranked] *Anthemoideae* DC., Prodr. 6: 19. 1838 \equiv *Ptarmica* sect. *Anthemoideae* (DC.) Klok. & Krytzka in Ukrains'k. Bot. Žurn. 41(3): 3. 1984 \equiv *Ptarmica* ser. *Barrelieranae* Klok. & Krytzka, l.c. 3. 1984. – Lectotype (Klokov & Krytzka 1984): *Achillea barrelieri* (Ten.) Sch. Bip. in Flora (Regensb.) 38: 15. 1855 \equiv *Anthemis barrelieri* Ten., Fl. Nap. 2: 245. 1820 \equiv *Ptarmica barrelieri* (Ten.) DC., Prodr. 6: 19. 1838.
 \equiv *Achillea* sect. *Montanae* Heimerl, l.c. 131, 137. 1884. – Lectotype (hoc loco design.): *Achillea atrata* L.
 \equiv *Achillea* sect. *Chamaemelifoliae* Klok. & Krytzka in Ukrains'k. Bot. Žurn. 41(3): 7. 1984. – Type: *Achillea chamaemelifolia* Pourr.
 \equiv *Ptarmica* sect. *Lingulata* (Rchb. f.) Klok. & Krytzka, l.c. 2. – Type: *Ptarmica lingulata* (Waldst. & Kit.) DC. \equiv *Achillea lingulata* Waldst. & Kit.
 \equiv *Ptarmica* sect. *Macrophyllae* (Rchb.) Klok. & Krytzka, l.c. 2. – Type: *Ptarmica macrophylla* (L.) DC. \equiv *Achillea macrophylla* L.
 \equiv *Ptarmica* ser. *Ageratifoliae* Klok. & Krytzka, l.c. 3. – Type: *Ptarmica ageratifolia* (Sm.) Nyman \equiv *Achillea ageratifolia* Sm.
 \equiv *Ptarmica* ser. *Oxylobae* Klok. & Krytzka, l.c. 3. – Type: *Ptarmica oxyloba* DC. \equiv *Achillea oxyloba* (DC.) Sch. Bip.
 \equiv *Ptarmica* ser. *Rupestris* Klok. & Krytzka, l.c. 4. – Type: *Ptarmica rupestris* (Huter ex G. Beck) Nyman \equiv *Achillea rupestris* Huter ex G. Beck
 \equiv *Ptarmica* ser. *Clusianae* Klok. & Krytzka, l.c. 4. – Type: *Ptarmica clusiana* (Tausch) Schur \equiv *Achillea clusiana* Tausch
 \equiv *Ptarmica* ser. *Atratae* Klok. & Krytzka, l.c. 4. – Type: *Ptarmica atrata* (L.) DC. \equiv *Achillea atrata* L.

Nuclear and plastid DNA sequences allow to recognize a core group of *Achillea* sect. *Anthemoideae* species, whereas a few other species, traditionally treated as members of this section, appear scattered among more distal clades formed predominantly by members of *A.* sect. *Achillea*. Thus, no evidence for the monophyly of *A.* sect. *Anthemoideae* is yet available. Its core group always appears closely linked with *A. ligustica* All. (regarded here as part of *A.* sect. *Achillea*), a fact that may be relevant for the origin of *A.* sect. *Anthemoideae*.

We propose to circumscribe *Achillea* sect. *Achillea* in a wide sense, since taxa with yellow ligulate flowers, formerly classified under *A.* sect. *Filipendulinae* (DC.) Afan. (antedated by *A.*

sect. *Ageratium* Rchb. f.) appear intermingled with white-flowered taxa in our DNA trees. Only *A. ligustica* All., which is certainly not a member of the *A. nobilis* L. assembly (as suggested by Bässler 1963), and the group of *A. ochroleuca* Ehrh. occupy more isolated positions within *A. sect. Achillea*. The extremely polymorphic and reticulate polyploid complex of the *A. millefolium* aggregate, with several parallel series of 2x-4x-6x-8x taxa and native throughout the northern hemisphere, forms the “crown group” of the genus in our trees (Guo & al. 2004, 2005a). The type of the sectional name, *A. millefolium* L., has to be defined in a narrow sense and is limited to 6x cytotypes, widespread through Central and N Europe. It is particularly in this aggregate that the excessive splitting into sections and series by Klokov & Krytzka (1984) fails to reflect phylogenetic relationships.

***Achillea* sect. *Achillea* s. lat.** – Type: *Achillea millefolium* L., Sp. Pl.: 899. 1753 ≡ *Millefolium* Mill., Gard. Dict., abridged ed. 4: 905. 1754 ≡ *Achillea* sect. *Millefolium* (Mill.) W. D. J. Koch, Syn. Fl. Germ. Helv.: 372. 1837 – Type: *Achillea millefolium* L.
 = *Achillea* [unranked] *Millefoliatae* DC., Prodr. 6: 24. 1838 ≡ *Achillea* sect. *Millefoliatae* (DC.) Afan., Fl. SSSR 26: 75. 1961 ≡ *Achillea* ser. *Millefoliatae* (DC.) Klok. & Krytzka in Ukrain's'k. Bot. Žurn. 41(3): 8. 1984. – Type: *Achillea millefolium* L., l.c. 5.
 = *Achillea* [unranked] *Filipendulinae* DC., Prodr. 6: 27. 1838 ≡ *Achillea* sect. *Filipendulinae* (DC.) Afan., Fl. SSSR 26: 90. 1961. – Type: *Achillea filipendulina* Lam.
 = *Achillea* sect. *Ageratium* Rchb. f., Icon. Fl. Germ. 16: 64. 1854. – Type: *Achillea ageratum* L.
 = *Achillea* sect. *Crithmifolia* Ujhelyi in Ann. Hist.-Nat. Mus. Natl. Hung. 47: 41-55. 1975. – Type: *Achillea crithmifolia* Waldst. & Kit.
 = *Achillea* sect. *Micrantha* Klok. & Krytzka, l.c. 5. ≡ *Achillea* ser. *Micranthae* Klok. & Krytzka, l.c. 6. – Type: *Achillea micrantha* Willd.
 = *Achillea* ser. *Leptophyllae* Klok. & Krytzka, l.c. 6. – Type: *Achillea leptophylla* M. Bieb.
 = *Achillea* sect. *Ochroleucae* Klok. & Krytzka, l.c. 6. – Type: *Achillea ochroleuca* Ehrh.
 = *Achillea* sect. *Nobilis* Klok. & Krytzka, l.c. 6 ≡ *Achillea* ser. *Nobiles* Klok. & Krytzka, l.c. 7. – Type: *Achillea nobilis* L.
 = *Achillea* ser. *Virescentes* Klok. & Krytzka, l.c. 7. – Type: *Achillea virescens* (Fenzl) Heimerl
 = *Achillea* ser. *Micranthoides* Klok. & Krytzka, l.c. 7. – Type: *Achillea micranthoides* Klok.
 = *Achillea* ser. *Asplenifoliae* Klok. & Krytzka, l.c. 8. – Type: *Achillea asplenifolia* Vent.
 = *Achillea* ser. *Setaceae* Klok. & Krytzka, l.c. 8. – Type: *Achillea setacea* Waldst. & Kit.
 = *Achillea* ser. *Tanacetifoliae* Klok. & Krytzka, l.c. 8. – Type: *Achillea tanacetifolia* All.

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