RHEEDEA
Journal of the Indian Association for Angiosperm Taxonomy

RESEARCH ARTICLE

Vol. 31(1): 1–10 (2021)
ISSN: 0971-2313 (Print edition)
ISSN: 2582-2438 (Online edition)
https://dx.doi.org/10.22244/rheedea.2021.31.01.01

A taxonomic revision of the genus *Dolomiaea* (Asteraceae: Cardueae) in India

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Abstract: The genus *Dolomiaea* DC. (Asteraceae: Cardueae) is represented by three species in India. It is distributed in the alpine Himalaya and is often found in chasmophytic habitats. Recent advances in molecular phylogenetic studies have re-circumscribed the generic boundaries of *Dolomiaea* and hence a detailed taxonomic account of this genus in India is provided here. We recognize three species: *Dolomiaea baltalensis* Dar & Naqshi, *D. costus* (Falc.) Kasana & A.K.Pandey and *D. macrocephala* DC. ex Royle for India. *Dolomiaea macrocephala* and the heterotypic synonym of *D. costus*, *Aplotaxis lappa* Decne. are lectotypified.

Keywords: Lectotype, Nomenclature, Saussureinae, Taxonomy, Western Himalaya.

Introduction

The genus *Dolomiaea* DC. (Asteraceae: Cardueae) is represented by *c*. 21 species worldwide and is endemic to the alpine regions of China, India, Myanmar, Nepal and Pakistan (Huang, 1998; Wang *et al*., 2007; Funk *et al*., 2009; Shi & Raab-Straube, 2011; Shen *et al*., 2020). It is one of the well-established genera in subtribe Saussureinae N.Garcia & Susanna (earlier informally known as the *Saussurea* or *Saussurea* – *Jurinea* group) and occurs up to 5000 m elevation.

The genus was established by Candolle (1833) honouring French geologist Deodat de Dolomieu. According to the protologue, *Dolomiaea* is closely related to *Saussurea* DC. and this concept was accepted for a long time until Boissier (1888) shifted the type species to *Jurinea* Cass., indicating its close affinity with *Jurinea*. It was treated under *Jurinea* section *Subacaules* Benth. by Bentham and Hooker (1873) in their *Genera Plantarum* and this treatment was followed by most other botanists including Hooker (1881) and Hajra (1995). However, Ling (1965) treated *Dolomiaea* as a separate genus more closely related to *Saussurea* than to *Jurinea*, based on the morphology of the pappus, corolla and pollen grains. The genus *Vladimiria* Iljin was also included within the circumscription of *Dolomiaea* by Ling (1965) and was recognized as a section based on similarities in habit and inflorescence. Although the infrageneric limits within the present day subtribe Saussureinae have remained unclear for a long time (Susanna & Garcia-Jacas, 2009; Raab-Straube, 2017; Herrando-Moraira *et al*., 2020), grouping of genus *Dolomiaea* into two sections has been widely accepted (Chu, 1986; Wang *et al*., 2007): (i) *D.* sect. *Dolomiaea* characterized by short, compact style branches with round apex and (ii) *D.* sect. *Vladimiria* (Iljin) C.Shih with long, spreading and acute style branch tips.

Dolomiaea has been characterized morphologically by naked and alveolate receptacles, pluriseriate pappi and scabrid pappus bristles (Wang *et al*., 2007). However, there are many ambiguities in the circumscription of this genus due to the presence of overlapping characters and phenotypic plasticity. Therefore, *Dolomiaea* has been of great interest for systematists and has remained an integral part of the *Saussurea* – *Jurinea* group. However, recent studies have shown that *Dolomiaea* is a distinct genus and has been recovered as a well-supported

Received: 31.10.2020; *Revised & Accepted*: 24.02.2021
Published Online: 31.03.2021

clade in molecular analyses (Wang *et al*., 2007; Herrando-Moraira *et al*., 2020; Kasana *et al*., 2020).

The genus is medicinally important and some of the species such as *D. souliei* (Franch.) C.Shih, and *D. wardii* (Hand.-Mazz.) Y.Ling are known to exhibit anti-bacterial activity and have been used traditionally as herbal medicines (Li & Sheng, 2013). *Dolomiaea macrocephala* DC. ex Royle (also referred to in various publications as *Jurinea dolomiaea* Boiss.) is popularly used for its aromatic roots in the incense industry, as an insect repellent and also to treat fever, rheumatism, gout, etc. (Sharma *et al*., 2004). It has also been reported to be forage for the alpine lagomorph *Ochotona roylei* Ogilby, commonly known as Himalayan mouse hare or Royle's pika (Bhattacharyya *et al*., 2013).

In India, *Dolomiaea* is represented by three species distributed in the Himalaya (Fig. 1). As the genus is medicinally important and has undergone various taxonomic changes in recent years, a comprehensive account in India has been provided in the present communication with details on phenology, distribution, conservation status and type information.

Taxonomic treatment

Dolomiaea DC. in Guillem., Arch. Bot. (Paris) 2: 330. 1833; Hook. f., Fl. Brit. Ind. 3(8): 378. 1881; Dar & Naqshi, J. Bombay Nat. Hist. Soc. 87(2): 278. 1990; Karthik. *et al*., Fl. Pl. India 1: 321. 2009. *Type*: *Dolomiaea macrocephala* DC. ex Royle.

Perennial herbs, mostly acaulescent, rarely long-stemmed. Leaves dentate to pinnatifid, rarely entire; ovate, obovate or lanceolate, adaxial surface mostly hirsute spinulose, abaxial surface usually densely woolly. Capitula solitary to numerous, always homogamous, arranged in centre of leaf rosette, rarely terminal. Involucre campanulate, bracts multiseriate. Receptacle alveolate, without scales. Corolla pentamerous, actinomorphic, purple to purplish–blue, glabrous to gland dotted. Staminal filaments glabrous; anthers sagittate, tails lacerate. Cypsela obovate, obpyramidal or broadly obconic, isodiametric, apical pericarpal rim glabrous, sometimes rugulose to squamulose, straw-coloured, often with black wavy fringes. Pappus uni- or multiseriate, subequal or outer row shorter; bristles yellowish, scabrid or plumose; basally connate into a ring, caducous as a whole.

Habitat: It is found in alpine regions in chasmophytic habitats like rock crevices, open slopes or dry areas.

Distribution: China, India, Myanmar, Nepal and Pakistan.

Notes: With the advancement of molecular techniques, several phylogenetic studies (Wang *et al*., 2007; Susanna & Garcia-Jacas, 2009; Shen *et al*., 2020) have been carried out to investigate the systematic position of *Dolomiaea* and to assess its generic limits. In recent studies (Herrando-Moraira *et al*., 2020; Kasana *et al*., 2020) the genus has been re-circumscribed to include the genera *Aucklandia* Falc., *Bolocephalus* Hand.-Mazz. and *Frolovia* (DC.) Lipsch. It has also been suggested now that *Dolomiaea* is more closely related to *Jurinea* and not to *Saussurea* as was earlier believed.

Key to the species in India

1. Capitula terminal on stems; pappus uniseriate ..... *D. costus*
1. Capitula clustered in leaf rosettes; pappus multiseriate 2
2. Leaves adaxially tomentose, entire to irregularly lobed ..... *D. baltalensis*
2. Leaves adaxially hirsute, pinnatifid ..... *D. macrocephala*

Dolomiaea baltalensis Dar & Naqshi, J. Bombay Nat. Hist. Soc. 87(2): 278. 1990. *Type*: INDIA, **Kashmir**, Baltal, Sonmarg, Sind valley, *G.H. Dar* 3899 (holo KASH; iso KASH, E [E00385497 digital image!]). **Fig. 2**

Perennial herbs, acaulescent. Leaves ovate to elliptic ovate, rounded at the base, 13–16 × 5–7 cm, entire to irregularly lobed, dentate, adaxial surface

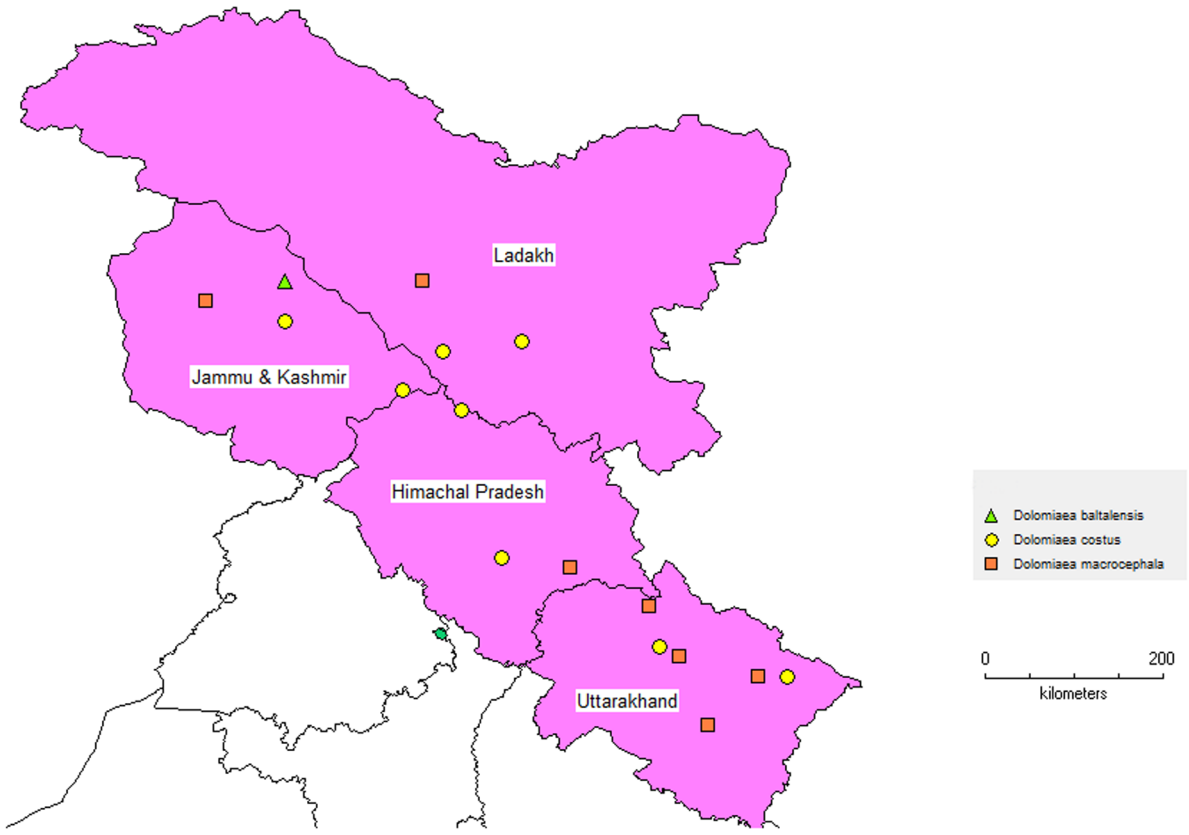

Fig. 1. Distribution map of the genus *Dolomiaea* DC. in Guillem. in India, showing some of the specimens examined in this study (drawn using DIVA-GIS).

tomentose, abaxial surface densely woolly, petiolate. Petiole 3 to 10 cm long, woolly, sometimes sheathing at the base. Capitula numerous, 7–24 in number, 1.5–2.2 × 0.5–1.5 cm, discoid, peduncle up to 5 cm. Involucral bracts in many rows, acuminate, ovate-lanceolate, imbricate. Florets actinomorphic. Corolla tubular, pinkish-purple, up to 1.5 cm long. Staminal filaments glabrous; anthers sagittate, tails lacerate. Cypsela cuneate-obovoid, 4-angled with an apical pericarpal rim, glabrous, 2.1–2.7 × 0.7–0.9 mm, grey with black wavy fringes. Pappus multiseriate with scabrid bristles, unequal, brown, deciduous as a whole.

Flowering & fruiting: Flowering and fruiting from August to September.

Habitat: It grows on rocky slopes above meadows elevations of 3000 to 3500 m.

Distribution: India, endemic to Jammu & Kashmir.

Specimens examined: INDIA, **Jammu & Kashmir**, Baltal, Sonmarg, Sind valley, 3000 m, 02.09.1982, *G.H. Dar* 3899 (E [E00385497 digital image]); Pranshur, Sonmarg, Sind valley, 3500 m, 27.08.1983, *G.H. Dar* 8325 (E [E00385498 digital image]).

Conservation status: This species is a point endemic and known only from the type locality, with only a few mature individuals. Since the type collection it has not been collected from any other potential localities (Singh & Pusalkar, 2020), and its habitat is also facing threats due to deforestation, unregulated road constructions etc. Therefore, the species is assessed here as Critically Endangered [criteria D] as per the guidelines of IUCN (2019).

Notes: *Dolomiaea baltalensis* is most similar to *D. macrocephala* in general appearance but differs from the taxon by its tomentose adaxial leaf surface, entire

Fig. 2. Type images of **a.** *Dolomiaea baltalensis* Dar & Naqshi (http://data.rbge.org.uk/herb/E00394933) and **b.** *Dolomiaea macrocephala* DC. ex Royle (http://data.rbge.org.uk/herb/E00385497) (© Royal Botanic Garden, Edinburgh.)

to irregularly lobed leaf lamina and longer peduncles (0.5–4.5 cm long) against hirsute adaxial leaf surface, pinnatifid leaves and shorter peduncles (0.5–1.5 cm long) in *D. macrocephala*.

Dolomiaea costus (Falc.) Kasana & A.K.Pandey, Phytotaxa 450(2): 184. 2020. *Aucklandia costus* Falc., Ann. Mag. Nat. Hist. 6: 475. 1841. *Theodorea costus* Kuntze, Revis. Gen. Pl. 1: 368. 1891. *Saussurea costus* (Falc.) Lipsch., Bot. Zhurn. (Moscow & Leningrad) 49: 131. 1964. *Lectotype* (designated by Lipschitz, 1979): INDIA, **Kashmir**, *Falconer s.n.* (K [K000372736 digital image!]).

Aplotaxis lappa Decne., Voy. Inde [Jacquemont] 4 (Bot.): 96, t. 104. 1844. *Saussurea lappa* (Decne.) Sch.Bip., Linnaea 19(3): 331. 1846. *Saussurea lappa* (Decne.) C.B.Clarke, Compos. Ind. 233. 1876, isonym. *Aucklandia lappa* (Decne.) Decne., Iconogr. Cormophyt. Sin. 4: 643, f. 6700. 1875. *Lectotype* (designated here): INDIA, Kashmir, *V. Jacquemont* 727 (P [P00602864 digital image!]). **Fig. 3**

Perennial herbs, erect, 1–3 m tall. Stem simple, pubescent above, 0.8–2 cm in diam. Basal leaves membranous, 10–12 × 7–9 cm, irregularly toothed; petiole 4–30 cm, lobately winged. Cauline leaves sessile or shortly petiolate, 14–16 × 9–11 cm. Leaves gland dotted or pubescent abaxially, hirsute adaxially, margin dentate or mucronate, apex acute. Capitula homogamous, sessile, solitary or in cluster of 3–5, usually terminal, 2.5–3.5 × 1.5–2 cm. Involucral bracts acuminate, ovate-lanceolate, sparsely arachnoid, purple. Corolla dark violet-purple, tubular, 1.5–1.8 cm long. Anther tails lacerate. Cypsela cylindrical, brown, curved, compressed, 0.6–1 cm long. Pappus brown, feathery, plumose, 1.3–1.9 mm.

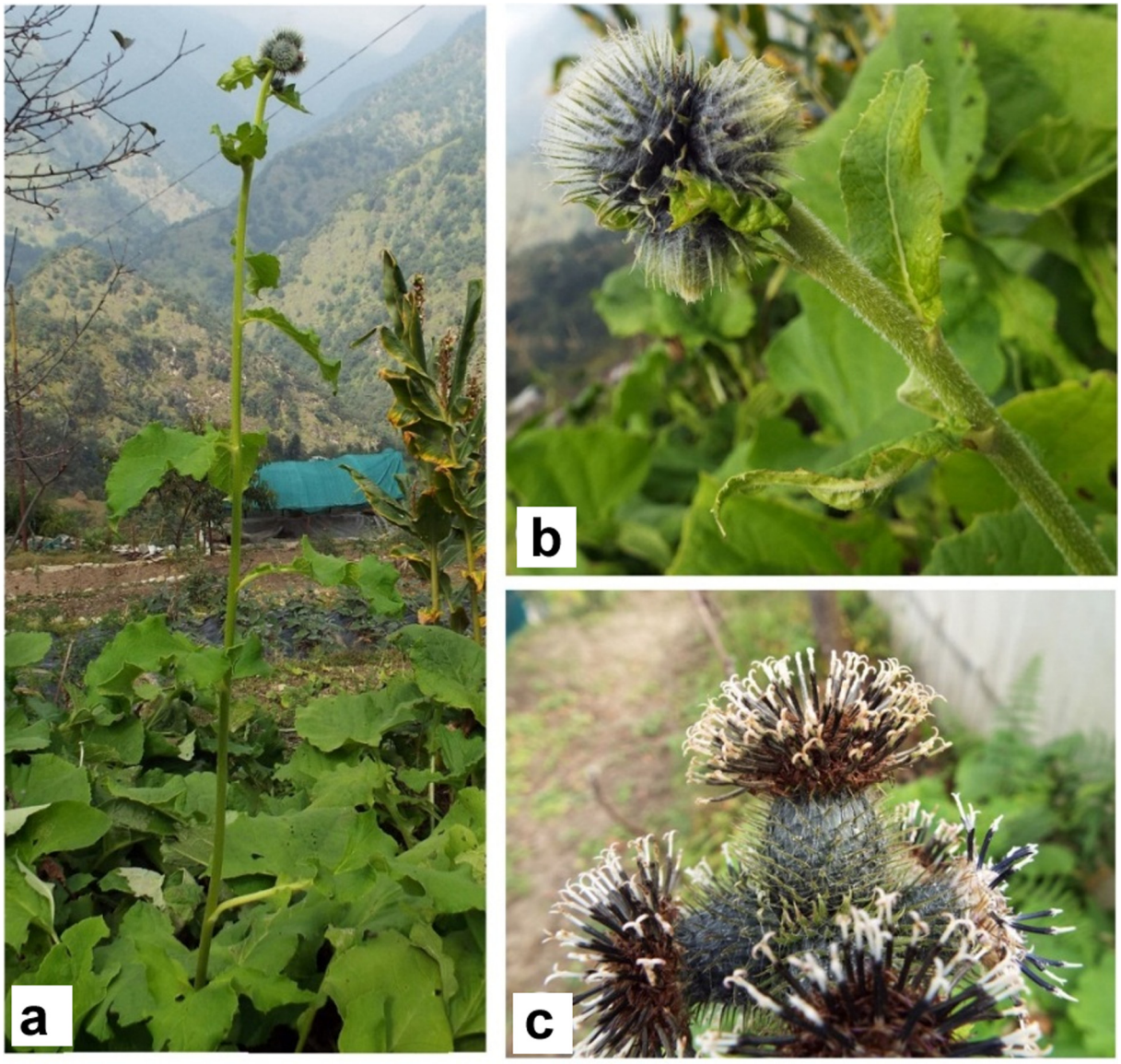

Fig. 3. *Dolomiaea costus* (Falc.) Kasana & A.K.Pandey: **a.** Habit; **b.** Pubescent stem; **c.** Cluster of capitula (images by S. Kasana).

Flowering & fruiting: Flowering and fruiting from July to October.

Habitat: Grows on rocky slopes and is widely cultivated due to its immense medicinal properties. It is found at elevations from 2100 to 4500 m.

Distribution: China (cultivated), India and Pakistan.

Specimens examined: INDIA, **Himachal Pradesh**, Chamba district, Pangi Valley, Sural, 3200 m, 18.07.2010, *Pawan K. Rana* 30612 (PUN); Kinnaur district, Chitkul, 17.08.1973, *K.P. Janardhanan* 52774 (BSD); Nichar, 2300 m, 28.05.1962, *N.C. Nair* 22065 (BSD); Upper Bashahr Forest Division, MFP Branch 01.09.1951, *s.coll.* (DD); Kullu district, Kullu, Jalori pass, 3300 m, 10.06.1990, *Daya Singh* 16422 (PUN); Lahul Spiti district, 3000 m, 01.09.1961, *N.C. Nair* 16669 (DUH); Lahul, Koksar, 05.09.1985, *P.K. Hajra* 76995 (BSD); Koksar (cult.), 3200 m, 02.08.1971, *U.C. Bhattacharyya* 44987 (BSD); Sissu, 3500 m, 26.06.1958, *M.A. Rau* 5919 (BSD); Sissu, 3079 m, 05.07.1938, *N.L. Bor* 12320 (DD); Jahlma, Nalda – Jasrath reserve, Pattan valley, 2896 m, 10.06.1958, *S.P. Sethi & R.S. Negi* 304 (DD); Kyelong, 3139 m, 14.07.1941, *N.L. Bor* 9934 (DD); Mandi district, Chhatru, 3375 m, 05.09.1961, *N.C. Nair* 16669

(BSD); **Jammu and Kashmir**, Thajwas mountains, 3800 m, 18.06.1959, *T.A. Rau* 9563 (BSD); Kunpathri in Tilal, 3048 m, 13.08.1909, *Keshavanand* 1515 (DD); Kashmir, 01.08.1891, *J.C. McDonell s.n.* (DD); Badzulkod nullah, Liddar valley, 3962 m, 01.08.1893, *J.F. Duthie s.n.* (DD); Liddar valley, 3353 m, 21.07.1993, *J.F. Duthie* 13106 (DD); Jaju Basa to Guric, 26.09.1838, *Falconer's collectors s.n.* (DD); Kamri pass, 3962 m, 01.08.1892, *s.coll.* 12582 (DD); Ramban, 27.06.1925, *Shor Singh s.n.* (DD); Sind valley, 3048 m, 13.08.1883, *J.F. Duthie* 13584 (DD); Keyan forest, Kawnah basin, Kishanganga valley, 2743 m, 12.07.1906, *Keshavanand* 207 (DD); Kilshai Bala in Tilai, 3353 m, 25.08.1909, *Keshavanand* 1576 (DD); Kishanganga valley, Shakhara stream, Jagram forest, 3353 m, 05.08.1906, *Keshavanand* 355 (DD); Baltistan, Dras valley, 3353 m, 22.08.1893, *J.F. Duthie s.n.* (DD); Sonmarg, Sind valley, 2743 m, 05.08.1891, *G.A. Gamma s.n.* (DD); Srinagar, Dhara Mahadev, 2944 m, 16.06.2015, *Sumeet Kour* 2317 (KASH); Sonmarg, 2700 m, 10.09.1975, *A.R. Azad* 1136 (KASH); Kashmir, Simthan quarter, 3700 m, 26.07.1974, *Gurcharan Singh* 2914 (KASH); Pir Panjal range, 3010 m, 12.07.1975, *s.coll.* 1356 (KASH); Kashmir, Diison nala, 3100 m, 12.09.1988, *Shoukat Ara* 21 (KASH); **Uttarakhand**, Chamoli district, Dronagiri, *P.K. Hajra & Bipin Badoli* 87551 (BSD); Chamoli, North of Bumpa, 3800 m, 06.09.1975, *B.D. Naithani* 56102 (BSD); Gharwal district, Buhna, 3500 m, 15.06.1959, *M.A. Rau* 10209 (BSD); Rudraprayag district, Triyuginarayan, GB Pant NIHE, Rural Technology Centre, 2000 m, 05.10.2017, *Shruti Kasana* 1743, 1744 (DUH).

Conservation status: The species is in high demand due to the presence of bioactive compounds such as Costunolide and Cynaropicrin (Pandey *et al*., 2007) and is listed in Appendix I of CITES. It is overharvested for its aromatic roots and it has been reported that the natural population is decreasing rapidly (Anonymous, 2011; Sharma *et al*., 2019). This species is assessed as Critically Endangered [CR A2(c,d)] in the IUCN Red List of Threatened Taxa. In our field explorations also, we came across only one population in the wild (near Lahaul-Spiti, Himachal Pradesh) but found the species in cultivation at various locations.

Notes: Victor Jacquemont made extensive collections for the Museum d' Histoire Naturelle to the East for Voyage dans l'Inde and his specimen from Kashmir, India, is the original material for *Aplotaxis lappa*. In the protologue, only the collection locality is mentioned and no type was designated. A thorough search for the original material at BR, P, PC and G, where Jacquemont's collections are reportedly located revealed one of the original material agreeing well with the protologue (*Jacquemont* 727 at P [P00602864 digital image!]) and is hence designated here as the lectotype following Art. 9.3 of the Shenzhen code (Turland *et al*., 2018).

Dolomiaea macrocephala DC. ex Royle, Ill. Bot. Himal. Mts. [Royle] pt. 5: t.57. 1835. *Carduus macrocephalus* Desf., Fl. Atlant. 2: 245. 1799. *Carduus macrocephalus* Wall., Numer. List [Wallich] n. 2904. 1831. *nom. nud. Saussurea religiosa* Royle, Ill. Bot. Himal. Mts. [Royle] pt. 8: 251. 1835; *Carduus nepalensis* Spreng. ex DC., Prodr. [A.P. de Candolle] 6: 542. 1838: *Jurinea macrocephala* (DC. ex Royle) Benth. ex C.B.Clarke, Compos. Ind. 237. 1876, *nom. illeg*. *Jurinea dolomiaea* Boiss. Fl. Orient. (Boisser) 311. 1888. *Jurinea himalaica* R.R.Stewart, Fl. W. Pakistan Annot. Cat. 757. 1972, *nom. illeg. Jurinella macrocephala* (DC. ex Royle) Aswal & Goel, Indian J. Forest. 11(4): 339. 1989. *Lectotype* (designated here): INDIA, **Gosain Than**, Kumaon, *Wallich* 2904 (E [E00394933 digital image!]). *Isolectotypes*: (G [G00474692, G00474688 digital images!], P [P00705232 digital image!]).

Jurinea himalaica var. *tibetica* R.R.Stewart, Fl. W. Pakistan 757. 1972. *Jurinea dolomiaea* var. *tibetica* (R.R.Stewart) H.B.Naithani, Fl. Pl. India, Nepal & Bhutan 230. 1990. *Jurinella macrocephala* var. *tibetica* (R.R.Stewart) Karthik. & Moorthy, Fl. Pl. India 242. 2009. *Type*: **Baltistan**, Burji La, 12000 ft, *Clarke* 29887A (*Holo* K [not seen]). **Figs. 4 & 5**

Perennial herbs, acaulescent. Leaves petiolate, oblong-obovate, 20–30 cm long, lobes pinnatifid,

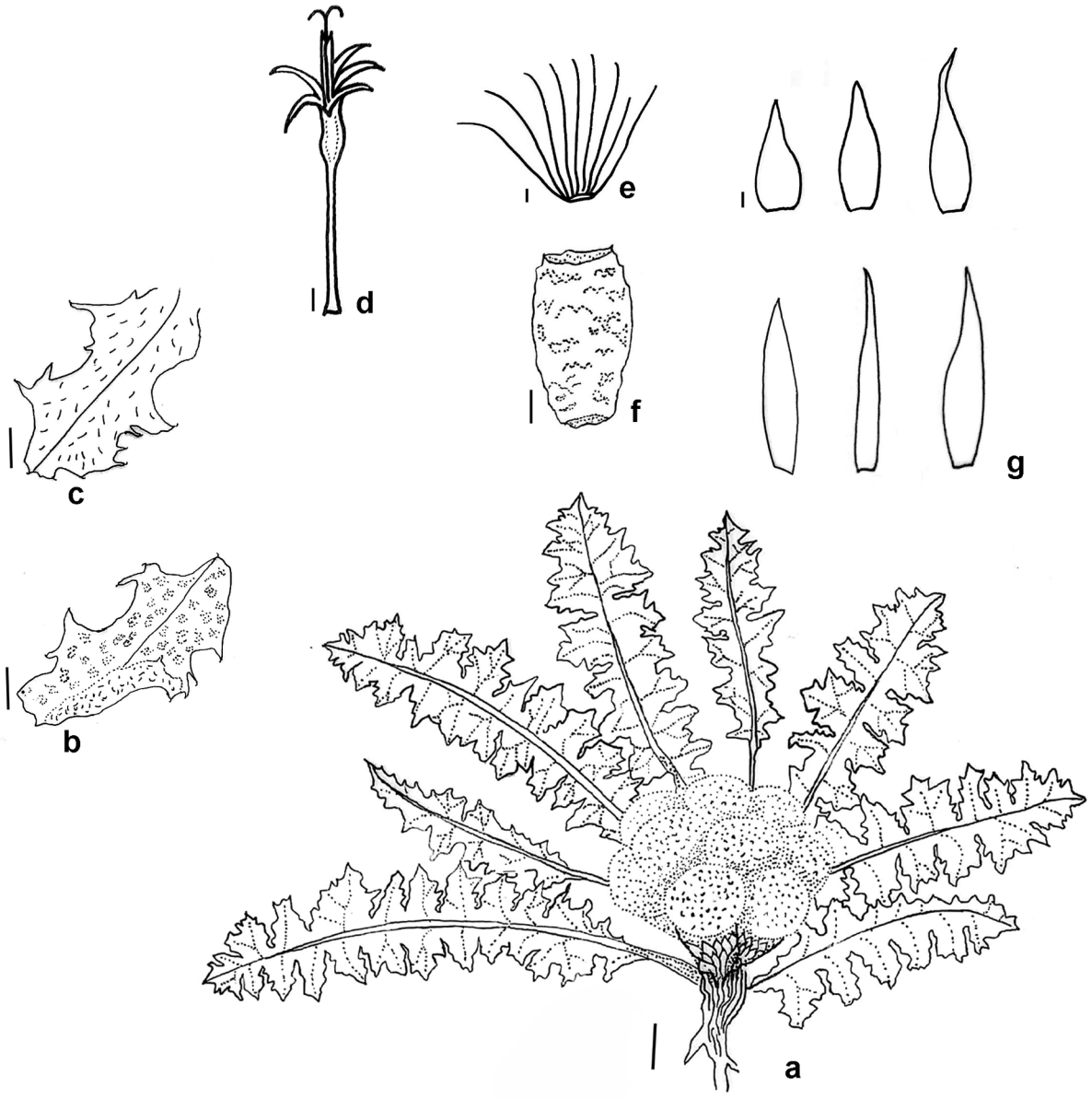

Fig. 4. *Dolomiaea macrocephala* DC. ex Royle: **a.** Habit; **b.** Enlarged portion of leaf with densely woolly abaxial surface; **c.** Enlarged portion of leaf with hirsute adaxial surface; **d.** Floret; **e.** Pappus; **f.** Cypsela; **g.** Involucral bracts. [scale = 1mm (b-g); 2 cm (a)] (from *S. Kasana* 1713; drawn by S. Kasana).

denticulate, adaxial surface hirsute, abaxial densely woolly. Capitula numerous, 3–15 in number, sessile to shortly peduncled, 4–5 × 2.5–3.2 cm, tomentose. Involucral bracts multiseriate, ovate to elliptic-lanceolate, scabrid, scarious. Corolla tubular, linear, 2–3.5 cm long, purple. Filaments glabrous. Anther base caudate; tails lacerate. Cypsela obovate, compressed, curved, glabrous, with black wavy fringes, apex truncate. Pappus plumose, brown, deciduous as a whole.

Flowering & fruiting: Flowering and fruiting from July to October.

Habitat: Grows in alpine meadows, on rocky slopes and in rock crevices, at elevations from 3500 to 4600 m.

Distribution: India, Nepal and Pakistan.

Specimens examined: INDIA, **Uttarakhand**, Rudraprayag district, Tungnath, 3650 m, 03.10.2017, *Shruti Kasana* 1713, 1714 (DUH);

Fig. 5. *Dolomiaea macrocephala* DC. ex Royle: **a & b.** Habit; **c.** Habitat (images by S. Kasana).

Garhwal, near Chandrashila peak, 4090 m, 03.10.2017, *Shruti Kasana* 1735 (DUH).

Conservation status: During our field visits (from 2017–2020), we observed the species to be of occasional distribution but the population size has decreased over these years possibly due to over exploitation for its medicinal properties. We have also observed that its natural habitat is under threat due to increased tourist influx, leading to a decline in its extent of occurrence and the number of populations. Therefore, as the species is facing high risk of extinction from the wild, it has been assessed here as Vulnerable [Criterion B1 a,b(i,ii,iv)] following the guidelines of IUCN (2019).

Notes: Candolle described *Dolomiaea macrocephala* based on Wallich's collection (Catalogue No. 2904) from India, Gosain Than, Kumaon. However, he did not designate the type or mention the herbarium where the specimen was kept. We traced four original materials at three different herbaria: E (E00394933 digital image!), G (G00474692, G00474688 digital images!) and P (P00705232 digital image!). As the specimen at E (E00394933) agrees well with the protologue, we designate it as the lectotype following Art. 9.3 of the Shenzhen code (Turland *et al*., 2018).

The placement of this species in genus *Dolomiaea* was unclear and many authors (Hooker, 1881; Pusalkar & Singh, 2012; Singh & Pusalkar, 2020) accepted it under the genus *Jurinea*. This confusion arose due to the transfer of *D. macrocephala* to *Jurinea* by Pierre Edmond Boissier in 1888. When Boisser transferred the species, the epithet '*macrocephala*' was

preoccupied within *Jurinea* and hence, a replacement name was given as *Jurinea dolomiaea* Boiss. By applying this taxonomic change, the type of genus *Dolomiaea* was implicitly excluded by Boissier and hence the genus *Dolomiaea* was left with no type. This increased the existing confusion within *Saussurea s.l.* (now known as subtribe Saussureinae). However, recent molecular work (Herrando-Moraira *et al*., 2020) has clearly shown that this species lies in the *Dolomiaea* clade. Also, detailed morphological investigation shows that it should belong to *Dolomiaea* rather than *Jurinea* due to the absence of scales on the receptacle and yellowish pappus bristles that are not inserted on a conic cupule in *Dolomiaea* as compared to the presence of short scales on the receptacle and white pappus bristles that are inserted on a conic cupule in *Jurinea*.

Acknowledgements

Authors are thankful to the Herbarium curators of DD, BSD, KASH and PUN for permission to consult the herbarium specimens. Thanks are due to Dr. Kanchi N. Gandhi (Harvard University) for his help in clarifying nomenclatural doubts. SK is thankful to the Council of Scientific and Industrial Research, New Delhi, India for the award of a Senior Research Fellowship.

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