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RESEARCH

Molecular and morphological data reveal a new species of *Sclerorhachis* (Compositae, Anthemideae) and the reassessment of another species of the genus

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Abstract
An expanded phylogenetic reconstruction based on the nuclear ribosomal DNA internal transcribed spacer region (nrDNA ITS) in conjunction with a multivariate statistical analysis of morphological characters revealed a new species and the re-acknowledgement of another one in *Sclerorhachis* (Compositae, Anthemideae). The newly revealed species, *Sclerorhachis ferdowsii*, has been previously included in the so-called *S. platyrachis*-complex, but is easily distinguished as an independent species by its rhizomatous root system, sparsely paleate receptacles, coronate and costate achenes, the relatively smaller size of the capitula, and the smaller habit of the whole plant. Additionally, morphological and molecular data corroborated *S. paropamisica* as a distinct species rather than being conspecific with *S. platyrachis*. With these newly acknowledged taxa, the number of species in *Sclerorhachis* is now expanded to eight. A detailed morphological description, an illustration, and distribution maps for *S. ferdowsii*, along with an identification key for all species of *Sclerorhachis,* are provided.

Keywords Asteraceae · nrDNA ITS · Phylogeny · *Sclerorhachis platyrachis*-complex · Species nova

Introduction

Sclerorhachis (Rech.f.) Rech.f. (Compositae, Anthemideae) is a small genus endemic to SW Asia and includes six fragrant species that typically favor arid to semiarid habitats. The genus was characterized as comprising monocarpic perennial or biennial herbs with 3–4-pinnatisect leaves forming a rosette and almost leafless, loosely branched stems. Its discoid capitula are arranged in lax corymbs, bear persistent to readily deciduous paleae on their receptacles, and develop ecoronate to coronate achenes with 4–7 inconspicuous ribs and a pericarp furnished with myxogenic cells (Oberprieler et al. 2007, 2022). The taxonomy of *Sclerorhachis* species has been controversial for a long time. Due to a limited number of informative morphological characters and a relatively low number of specimens analysed by previous taxonomists, species circumscriptions were based on a few morphological characters only. For example, *S. platyrachis* (Boiss.) Podlech ex Rech.f. was described as being different from *S. paropamiscica* only by its larger habit and the slightly larger size of the capitula (Tzvelev 1961). As a consequence, some authors (Rechinger 1986; Mozaffarian 2009) reduced *S. paropamiscia* to synonymy of *S. platyrachis*. Additionally, species delimitation in *Sclerorhachis* is hampered by morphologically intermediate individuals that have been reported to arbitrate between quite dissimilar species (e.g., *S. kjurendaghi* (Kurbanov) Kovalevsk. and *S. platyrachis*, Hassanpour et al. 2018), implying that hybridization may have played an important role in the evolution of the genus.

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Quite recently, species boundaries in *Sclerorhachis* have been evaluated using sequence information from both the nuclear ribosomal DNA (nrDNA ITS and ETS) and the chloroplast DNA (cpDNA *rpl*32–*trn*L (UAG) intergenic spacer region) and resulted in the description of the new species *S. binaludensis* Sonboli. Additionally, this study revealed two new records of *S. caulescens* (Aitch. & Hemsl.) Rech.f. and *S. kjurendaghi* to the flora of Iran that had been hitherto ascribed to *S. platyrachis* (Hassanpour et al. 2018). However, discordant results of different species delimitation methods in the mentioned study indicates that the species concept for the *S. platyrachis*-complex is still unclear.

Sclerorhachis platyrachis is subendemic to the Khorassan and Kopet Dagh floristic province in the Irano-Turanian region (Memariani et al. 2016a, b), and it is the most challenging species of the genus. In morphological respects, it is extremely polymorphic (Rechinger 1986; Hassanpour et al. 2018). The taxonomy of the species that encompasses numerous isolated populations (Rechinger 1986; Mozaffarian 2009) or independent species (Iranshahr 1979; Hassanpour et al. 2018) is highly controversial. According to recent species-delimitation approaches (Hassanpour et al. 2018), *S. platyrachis* populations reveal phylogenetic signals that may imply that the species comprises several independent evolutionary lineages that would merit species rank. However, species demarcation in the *S. platyrachis*-complex remained poorly understood due to limited sampling. In the present paper, we apply multivariate statistical analyses based on 30 quantitative and categorical morphological characteristics and phylogenetic analyses based on nrDNA ITS sequences of 31 sampled representatives of *Sclerorhachis* to (1) demonstrate the polyphyly of *S. platyrachis* and (2) delimit independent evolutionary lineages (species) in the *S. platyrachis*-complex.

Materials and methods

Plant material

The present study is based on extensive fieldwork during the past five years (2015–2020), as well as on the study of specimens deposited at FUMH, IRAN, M, MPH, MSB, TARI, and W. In addition, we studied images of type specimens of all species from Iran and neighboring countries by accessing those at K (http://apps.kew.org/herbcat/navigator.do), E (https://data.rbge.org.uk/search/herbarium), JACQ Virtual Herbaria (http://herbarium.univie.ac.at/database/search.php), Sweden virtual herbarium (http://herbarium.emg.umu.se), JSTOR Global Plants project database (https://plants.jstor.org), LE (http://en.herbariumle.ru), and G (http://www.ville-ge.ch/musinfo/bd/cjb/chg). We used the GeoCAT program to categorize the threat status of the species based on geographic range in the form of the extent of occurrence (EOO) and area of occupancy (AOO; Bachman et al. 2011; IUCN 2021). The distribution maps were prepared using ArcMap 10.3 (ESRI, Redlands, CA).

Molecular analyses

Taxon sampling

To examine phylogenetic relationships within the *Sclerorhachis platyrachis*-complex, 13 newly generated sequences of nrDNA ITS were added to the previous ITS alignment (Hassanpour et al. 2018). The new dataset includes all samples available to us, both for accessions provisionally determined as *S. platyrachis* and other specimens covering the complete geographical range of the genus (Fig. 1). For the phylogenetic reconstructions, representatives of three genera from the subtribe Handeliinae (i.e., *Handelia*, *Pseudohandelia,* and *Polychrysum*) were added as outgroups. Voucher information and accession numbers of all sequences are listed in Table 1.

DNA extraction, sequencing and analyses of sequence data

Total genomic DNA extractions were performed from silica-dried or herbarium material using the 2 × cetyltrimethylammonium bromide (CTAB) extraction protocol (Doyle and Doyle 1987). For amplification of the nuclear ribosomal DNA internal transcribed spacer (nrDNA ITS) the primers ITS5 (Sang et al. 1995) and ITS4 were used (White et al. 1990). Amplification products were checked on 1.5% TAE agarose gels and purified using PEG (Joly et al. 2006) and sequenced by BGI (Hong Kong).

The newly generated sequences were trimmed and assembled using Geneious v.6.1.2 (https://www.geneious.com). Sequences were added to the ITS dataset obtained from Hassanpour et al. (2018). The ITS sequences were aligned with Muscle as implemented in Geneious under default settings. Alignments were manually corrected in Geneious. The best substitution model for the alignment was selected using jModelTest v.2.1.4 (Darriba et al. 2012). The GTR + G model was determined as the best-fit model.

A combined dataset of two partitions (i.e., nrDNA ITS sequences data and binary characters for morphological data) was obtained. Phylogenetic analyses were performed using maximum likelihood (ML) and Bayesian inference (BI).

The ML analysis was carried out with IQ-TREE2 (Minh et al. 2020) using 1,000 bootstrap replicates and the ultrafast bootstrap approximation (UFBoot; Minh et al. 2013).

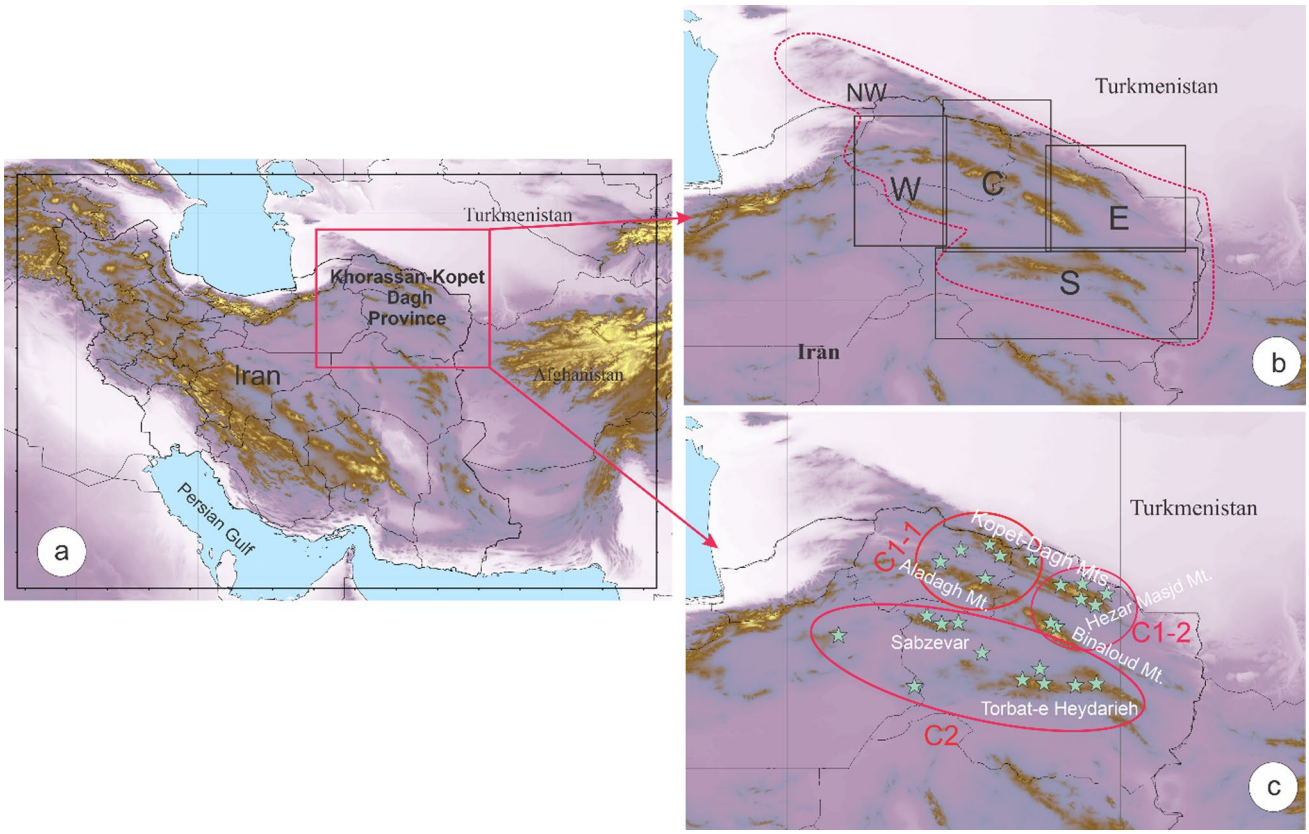

Fig. 1 Map of Iran and adjacent countries; **a** geographical position of the Khorassan and Kopet Dagh floristic province (KK) in northeastern Iran and southern Turkmenistan; **b** approximate zonation of the area, i.e., Northwestern (NW), Western (W), Central (C), Eastern (E) and Southern (S) parts; **c** distribution map of the specimens hitherto classified as *Sclerorhachis platyrachis*

Bayesian tree inference (BI) was performed using MrBayes v.3.1.2 (Hulsenbeck and Ronquist 2001) at the CIPRES portal in San Diego, CA, USA; (http://www.phylo.org/index.php/portal/) with default prior settings, for 20 million MCMC generations. The analyses' quality was checked by comparing likelihood values and parameter estimates from different runs in Tracer v.1.6 (http://tree.bio.ed.ac.uk/software/tracer/), and the initial 10% of the trees were discarded as burn-in. The remaining trees were summarized in a 50% majority-rule consensus tree.

Morphological analyses

Fifty-nine herbarium specimens of *Sclerorhachis* populations as Operational Taxonomic Units (OTUs) were subjected to morphometric measurements and scoring. The quantitative measurements were standardized by subtracting the mean from the value of each observed variable and then dividing it by the standard deviation. A mixed data matrix including 16 quantitative and 14 categorical variables was analyzed (Appendix 1) using Factorial Analysis of Mixed Data (FAMD) combined with mixed discriminant analysis (MDA). FAMD has been developed by Pagès (2004) and implemented in the R package FactoMineR (Lê et al. 2008) to simultaneously consider both categorical and quantitative variables while reducing the dimension of data. This analysis takes into account the quantitative variables as in a normal PCA and the categorical variables as in a multiple correspondence analysis (MCA). Mixed discriminant analysis (MDA) was performed by conducting a classical discriminant analysis using the forward stepwise procedure (tolerance = 0.0001) in XLSTAT v. 2020 (Addinsoft) on the main principal factors of FAMD (Abdesselam 2010) to evaluate whether species were clearly separated in morphospace.

Results

Molecular phylogeny

The Bayesian inference (BI) and Maximum Likelihood (ML) trees were nearly identical and, hence, only the BI tree is displayed in Fig. 2, including Bayesian posterior probabilities (PP) from the BI and bootstrap support (BS) values from the ML analyses. *Sclerorhachis* was found

Table 1 Taxa analyzed in the present study, with voucher information, and GenBank accession number. Taxa newly sequenced in the present study are marked with (*)

Taxon	Origin/voucher no	Accession No
Sclerorhachis binaludensis Sonboli	Iran, Khorassan-e Razavi, Neyshabur, Gerineh Mts., *Faghihnia* and *Zangooei 27768* (FUMH)	LC313924
	Iran, Khorassan-e Razavi, Mashhad, Feresgeh, *Faghihnia* and *Zangooei 17888* (FUMH)	LC313926
	Iran, Khorassan-e Razavi, Neyshabur, Kharv Mts., *Joharchi 44867* (FUMH)	LC313925
S. caulescens (Aitch. & Hemsl.) Rech.f	Afghanistan, Herat, Chashma-i-Obeh, *Podlech* and *Jarmal 29700* (MSB)	LC313931
	Afghanistan, Herat, Koh-i-Zyarat, *Podlech* and *Jarmal 29232* (M)	LC313930
	Iran, Khorassan-e Razavi, Torbat-e-Jam, *Joharchi 34078* (FUMH)	LC313927
	Iran, Khorassan-e Razavi, Sarakhs, *Joharchi 44805* (FUMH)	LC313929
	Iran, Khorasan-e Razavi, Sarakhs, Mazdavand, *Joharchi* and *Zangooei 16738* (FUMH)	LC313928
S. ferdowsii Hassanpour, Moazzeni & Sonboli (sp. nova)	Iran, Khorassan-e Razavi, Kardeh, *Joharchi* and *Zangooei 12943* (FUMH)	LC313941
	Iran, Khorassan-e Razavi, Heidary Wildlife Refuge, Kelidar village, *Atashgahi 7311* (Herbarium of Faculty of Sciences, Ferdowsi University of Mashhad)	OK663560* OK663561*
	Iran, Khorassan-e Razavi, N Mashhad, 1 km from Mareshk to Balghour, *Behroozian 46465* (FUMH)	OK663558* OK663559*
	Iran, Khorasan-e Razavi, Quchan road, Ardak to Talqur, *Sonboli, Kanani* and *Gholipour 1101* (MPH)	LC313939
	Iran, Khorassan-e Razavi, Kalat Nader, *Joharchi* and *Zangooei 16821* (FUMH)	LC313940
S. kjurendaghi (Kurbanov) Kovalevsk	Iran, North Khorassan, Gifan, *Memariani* and *Zangooei 38958* (FUMH)	LC313932
	Iran, North Khorassan, Ghorkhod, *Joharchi* and *Memariani 45030* (FUMH)	LC313933
	Iran, Semnan, Ahuvan pass, *Gholipour 2209* (MPH)	LC313934
	Iran, Semnan, 34 km E Shahrud road to Sabzevar, 1450 m, *Assadi* and *Mozaffarian 21206* (TARI!)	OK663572*
	Iran, Semnan, E Shahroud, Touran protected area, 25 km W Abbas Abad, *Joharchi* and *Memariani 46122* (FUMH)	OK663566*
S. leptoclada Rech.f	Iran, Khorassan-e Razavi, Gonabad-Ferdows road, *Ayatollahi* and *Zangooei 15186* (FUMH)	LC313935
	Iran, South Khorassan, Birjand, *Joharchi 45005* (FUMH)	LC313936
	Iran, South Khorassan, Birjand, *Faghihnia* and *Zangooei 30340* (FUMH)	LC313937
S. platyrachis (Boiss.) Podlech ex Rech.f	Iran, Khorassan-e Razavi, Torbat-e-Heydariyeh, *Hassanpour* and *Shahi-Shavvon 2363* (MPH)	LC313943
	Iran, Khorasan-e Razavi, Sabzevar, Soltan Abad, *Hassanpour* and *Shahi-Shavvon 2364* (MPH)	LC313944
	Iran, Khorasan-e Razavi, Kashmar, Bezgh Mts., *Assadi* and *Mozaffarian 35777* (TARI)	LC313945
	Iran, Khorasan-e Razavi, Sabzevar-Neyshabur road, *Rajamand* and *Bazargan 32097* (TARI)	LC313946
	Iran, Semnan, Turan Protected Area, 10 km from Talkhab to Garmab, *Freitag* and *Jadidi 29059* (TARI)	OK663571*
S. paropamisica (Krasch.) Kovalevsk	Iran, North Khorassan, SE Bojnurd, 6 km from Nodeh to Esfidan, *Rafeie* and *Zangooei 31548* (FUMH)	OK663562* OK663563*
	Iran, North Khorassan, Bojnurd, S Badranlou, Hamam Pileh, *Zangooei* and *Hosseinzadeh 24447* (FUMH)	OK663564* OK663565*
	Iran, North Khorassan, N Bojnurd, 1–2 km from Qezel Ghan to Bojnurd, *Memariani* and *Zangooei 42949* (FUMH)	OK663567* OK663568*

Table 1 (continued)

Taxon	Origin/voucher no	Accession No
S. polysphaera Rech.f	Afghanistan, Deh Kundi, W Shahrestan, *Rechinger 36811* (M)	LC313947
Handelia trichophylla (Schrenk) Heimerl	Iran, Khorasan-e Razavi, Dargaz, *Amiri 1689* (MPH)	LC313948
Pseudohandelia umbellifera (Boiss.) Tzvelev	Afghanistan, Kataghan, Pul-i Khumri, *Rechinger 33659* (S)	LC313949

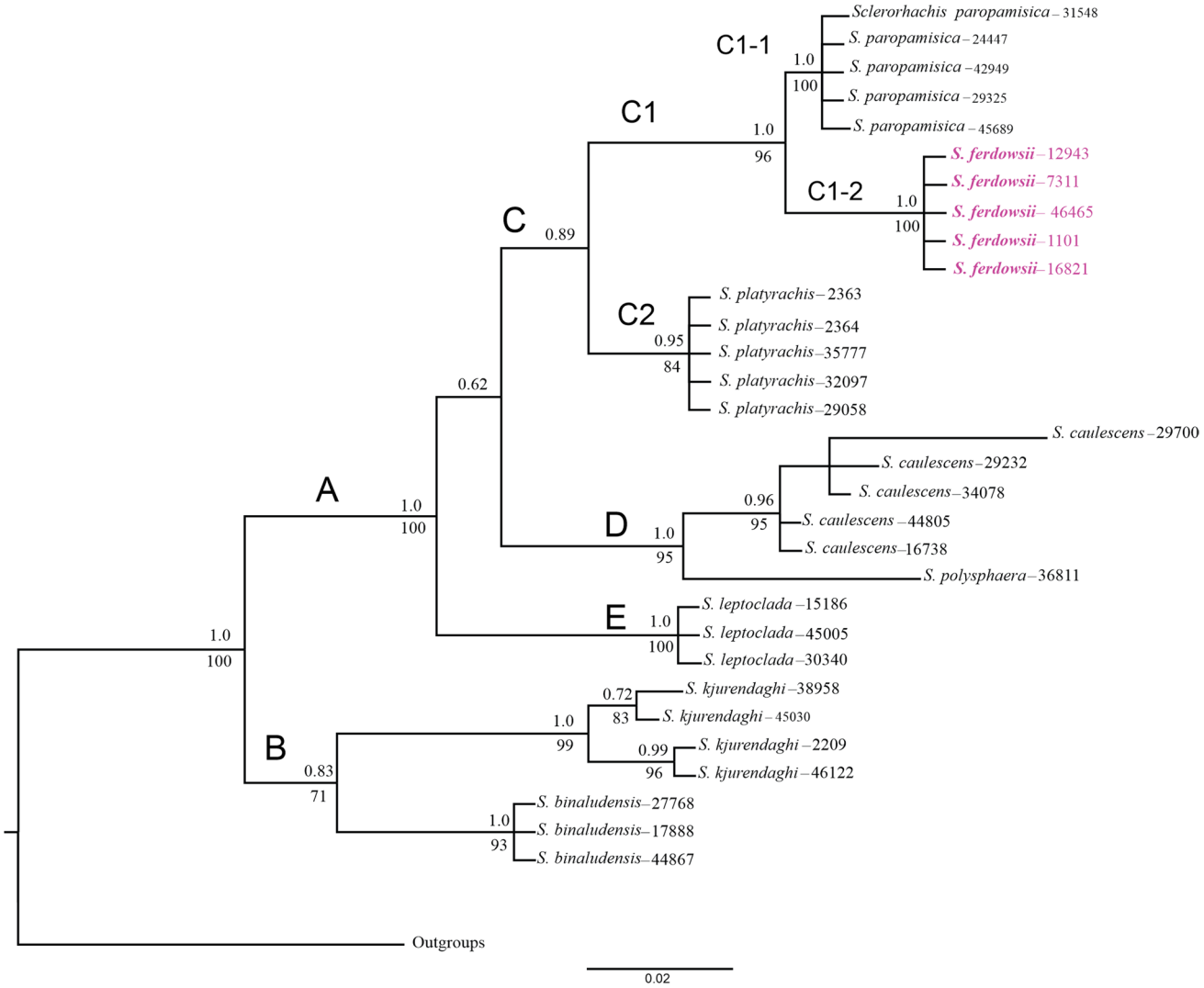

Fig. 2 Majority rule consensus tree of Bayesian analysis of nrDNA ITS sequences showing the phylogenetic position of *Sclerorhachis ferdowsii*. Numbers above branches indicate posterior probabilities and those below indicate maximum likelihood bootstrap values

being divided into two main clades with strong (clade A, BS 100, PP 1.0) and low (clade B, BS 71, PP 0.83) support, respectively. Within Clade A, three subclades, namely C, D, and E are observed. Subclade C with moderate support (BS-, PP 0.89) corresponds to species previously summarized under *S. platyrachis*, whereas subclade D with strong supports (BS 95, PP 1.0) comprises *S. caulescens* and *S. polysphaera*, and finally, subclade E includes *S. leptoclada* (BS 100, PP 1.0). The accessions of all species constituted monophyletic lineages, but *S. platyrachis* s.l. (subclade C) further split into three groups [corresponding to clades C1 (C1-1 and C1-2) and C2 when employing the same labels as used in Hassanpour et al. (2018)] with strong support (Fig. 2), where clade C1-1

corresponds to populations from the central part of Khorassan Kopet Dagh floristic province (KK; i.e., Aladagh Mts. and central part of Kopet Dagh range in Iran; BS 100, PP 1.0), clade C1-2 to [populations from Hezar–Masjed Mts. (eastern part of KK); BS 100, PP 1.0], and clade C2 to populations from Sabzewar-Kashmar and Torbat-e Heydarieh Mts. (the southernmost part of KK; BS 84, PP 0.95; see Fig. 1).

Morphological analyses

The factor analysis for mixed morphological characters (FAMD) identified three unique assemblages corresponding to *Sclerorhachis binaludensis, S. leptoclada* and *S. polysphaera* as circumscribed previously by Hassanpour et al. (2018). Additionally, three additional independent assemblages were recognized within *Sclerorhachis platyrachis* s.l. (Fig. 3a). These three assemblages correspond to the nrDNA ITS tree groups C1-1, C1-2, and C2. The first five factors of FAMD explained about 77.4% of the total variance. The first factor represents about 34.6% of the total variance and shows high (> 0.6) correlations with variation in characters such as stem diameter, collar width, basal leaves lamina length, basal leaves length (incl. petiole), rachis width, primary segments distance on basal leaves, capitula length, diameter and number, root system, and existence of dark brown midrib on involucre bracts. This axis separated the southern populations of KK (clade C2 in the nrDNA ITS tree), the population of *S. polysphaera* as well as the populations from the central Kopet Dagh range and Aladagh Mts as groups independent from other assemblages (Fig. 3a). The second factor explains 21.6% of the total variance and shows high correlations with characters such as paleae density and shape, achene surface vestiture and corona, and basal leaves terminal lobes shape; it separates *S. binaludensis*, the population from Aladagh and Iranian Kopet Dagh Mts. as well as a newly grouped of *Sclerorhachis* population from the eastern part of KK (Hezar–Masjed Mts., clade C1-2 in Fig. 2) from the remaining groups. Although the first two factors showed limited evidence of grouping in the studied specimens of *S. kjurendaghi* and *S. caulescens*, species were successfully separated by means of a discriminant function based on the five main principal factors of FAMD-MDA (Fig. 3b). The populations corresponding to *S. kjurendaghi* from the west of KK showed high intraspecific variation (e.g., both tap and rhizome root systems present, high variation observed in terms of number of capitula, plant sizes, and collar width). The Wilks criteria revealed an overall morphological variation between species (Wilks' lambda = 0.000, $p < 0.0001$). Percentages of correct classification of the MDA were high in all species (100%).

Discussion

The current study is the first to look into the *Sclerorhachis platyrachis*-complex from an integrative taxonomical perspective, including both morphological and molecular-phylogenetic data. It is based on a broader taxon and accession sampling, which has encompassed the complete range of morphological diversity observed in the study group as well as its complete geographical distribution.

Using only a single molecular marker might not give enough variety to sufficiently resolve trees. Applying a single marker would also result in homoplasy and cause the phylogenetic signals to be muddled (Alvarez and Wendel 2003; Capella-Gutierrez et al. 2014; Moazzeni et al. 2014; Urantowka et al. 2017; Tekpinar and Kalmer 2019). Although the phylogenetic tree inferred in the present study is based solely on nrDNA ITS, and the limited utility of using only one marker has been previously noted (Alvarez and Wendel 2003; Franzke et al. 2009; Capella-Gutierrez et al. 2014; Moazzeni et al. 2014), the results of our phylogenetic analysis combined with evidence from morphology and distribution data allow a well-settled taxonomic appraisal in terms of species delimitation in *Sclerorhachis*. Moreover, we discovered during our preliminary research as well as based on our results from 2018 (Hassanpour et al. 2018) that neither cpDNA nor ETS are helpful to our work and do not provide us with additional results, but rather a polytomy for the new species and its close relatives. Consequently, we did not use additional markers (especially cpDNA).

The findings of the present phylogenetic reconstruction were congruent with the previous, more limited study on the genus (Hassanpour et al. 2018) and confirmed the acceptance of 5 species acknowledged in that contribution, namely *S. binaludensis*, *S. caulescens*, *S. kjurendaghi*, *S. leptoclada*, and *S. polysphaera*. Additionally, however, our phylogenetic and morphological findings indicate that the *Sclerorhachis platyrachis*-complex consists of three monophyletic groups, which show considerable morphological discontinuities that would merit their acknowledgement as three different taxonomical entities.

If these three evolutionary units would be distributed allopatrically, classification as three morphologically and evolutionary distinct subspecies of a single species *S. platyrachis* would be the taxonomical solution suggested by the morpho-geographical method proposed by von Wettstein

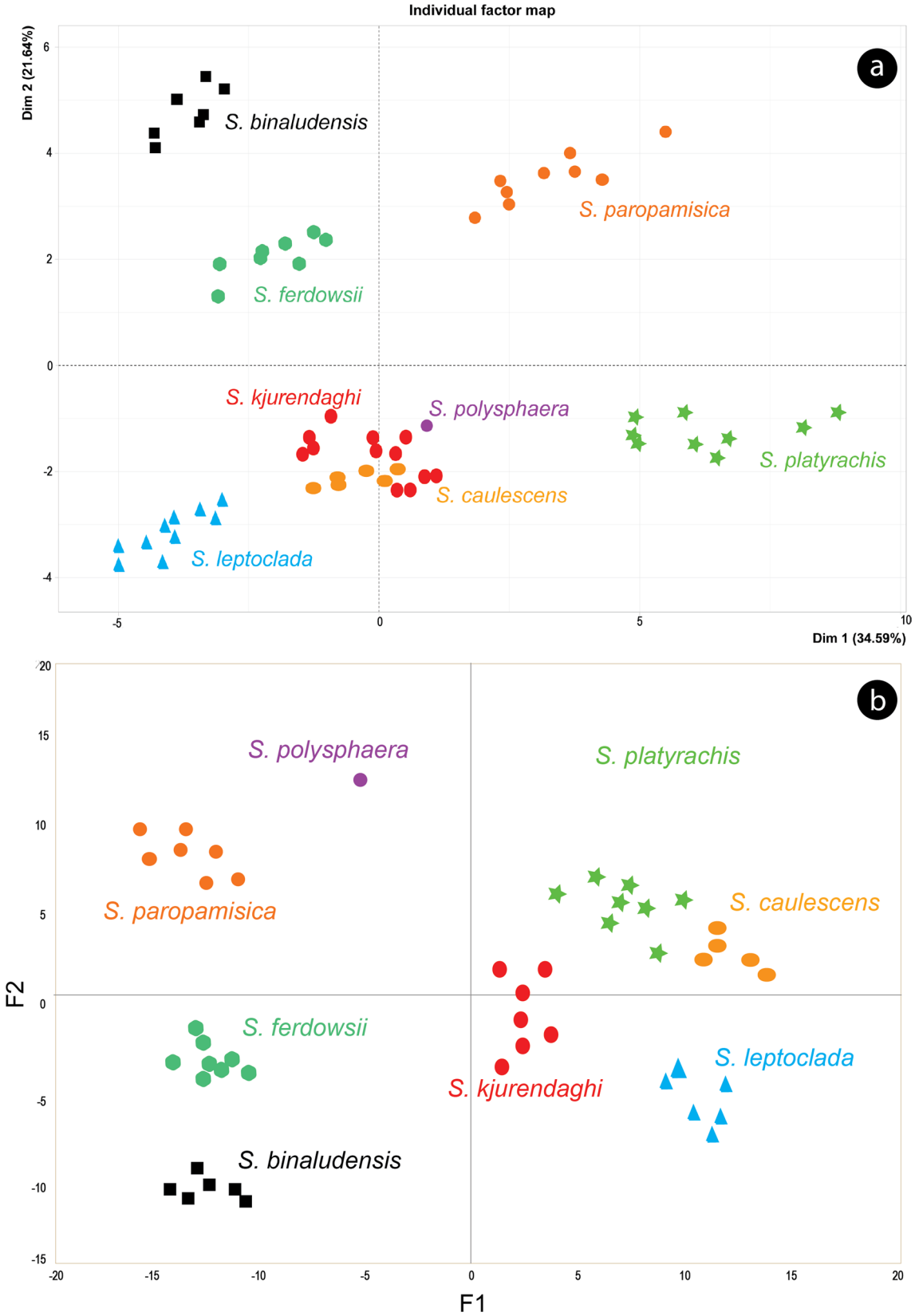

Fig. 3 **a** The first two axes with largest explanatory power of FAMD. Multivariate analysis of specimens of the *Sclerorhachis* was able to separate the 6 species, but not *S. caulescens* and *S. kjurendaghi*; **b** results of a MDA based on the first two principal components of the above FAMD analysis, showing the clustering of 8 species of *Sclerorhachis*

(1898). This author reasoned that closely-related, morphologically distinct and geographically coherent groups of populations should be classified as subspecies of a single species because the lack of ecological differentiation (and a presumed genetic compatibility) among these populations does not allow their joint presence in the same geographical region. Only after a further differentiation of those entities in ecological (and reproductive) terms, sympatry of those entities is possible, which should be acknowledged then with species-rank for them [see also Oberprieler (2022)]. Following this argumentation scheme in the *S. platyrachis*-group, we observe that populations of the closely-related clades C1-1 and C1-2 are distributed sympatrically in the Binalud (Quchan) area (see Figs. 1, 7). This should be considered a strong argument for having reached evolutionary independence from each other that should be acknowledged with species-rank for these two lineages. Additionally, there is also an ecological difference between the two lineages, with C1-1 growing in shallow valleys and flat slopes on wet clay soil and lineage C1-2 being restricted to dry screes on mountain ridges. This difference in ecology may therefore suffice to keep the two lineages apart even if their geographical overlap may expand and adds to the above arguments for their acknowledgement at species rank. Although these two lineages share some common features like a sparsely hairy receptacle and coronate and costate achenes, they are considerably dissimilar, with the specimens in clade C1-2 possessing a rhizomatous (vs. tap) root system, densely pubescent (vs. loosely pubescent) stems, solitary (vs. broadly paniculate) inflorescences, and exhibiting a smaller size of the whole plant (Fig. 4). The specimens of clade C1-1 (collected from Aladagh Mts. and central part of Kopet–Dagh range; Fig. 1) showed considerable similarities with *Sclerorhachis paropamisica*, e.g., mostly glabrous receptacle, coronate and costate achenes, 2–3 pinnatisected basal leaves, which had already been introduced and reported from the Paropamis Mts. (Turkmenistan) and Rechinger (1986) synonymized it under *S. platyrachis* (see below). As a consequence, clade C1-2 is described here as a species new to science, *S. ferdowsii* (see below).

Consequently, if these two sister-groups are classified as independent species, clade C2 (which is allopatrically distributed in Sabzevar and Torbat-e Heydarieh, but phylogenetically even more distant) should then be given species-rank, too. This lineage includes specimens from the south of KK, where Bunge obtained the type specimen for *S. platyrachis*. Therefore, these individuals should be accepted as *S. platyrachis* s.str.; a species that differs from the other two species of the species-group by the fact that they represent plants with higher and thicker stems, wider collars with larger petiole sheaths and lanate tomentum on the axil of basal leaves, broader capitula that are densely covered with paleae, and non-coronate and punctate achenes.

Taxonomic treatment

Sclerorhachis ferdowsii Hassanpour, Moazzeni & Sonboli, **spec. nov.**

HOLOTYPE: Iran, Khorassan-e Razavi, N Mashhad, 1 km from Mareshk to Balghour, 1809 m a. s. l., 36° 48′ 18.8″ N, 59° 34′ 29.84″E, 7 July 2019, *Moazzeni* and *Jafari 46635* (FUMH!; isotypes: FUMH!) (Figs. 4, 5).

Description: Rosulate polycarpic perennial herbs. Plants 25–40 cm high, with short rhizome producing several ramets. Stem erect, tenuous and rather leafless. Leaves grayish-green and pubescent; basal and lower cauline leaves 6–15 cm long and 2–4 cm wide, petioles 2–5 cm long, lamina bi-tri-pinnatisect; upper cauline leaves reduced, up to 1.5 cm long and 1 cm wide. Inflorescence solitary or lax corymb. Peduncle 5–8 cm long, discoid capitula 5–7, 10–12 mm in diameter. Involucre tomentose; involucral bracts in 2–3 rows with a narrowly membranous border. Receptacle loosely hairy. Achenes 2.5–3 mm long and < 1 mm wide, with five to six inconspicuous longitudinal ribs, corona > 0.1 mm long.

Distribution: Endemic to NE Iran (Hezar–Masjed Mts.).

Phenology: Flowering in May, fruiting in June.

Etymology: The species is named in honor of the great Persian poet "Hakim Abolghasem Ferdowsi Tousi" (940−1020 AD) whose tomb is located in Khorassan-e Razavi province, Iran.

Distribution and habitat: *Sclerorhachis ferdowsii* is a local endemic to NE Iran (Fig. 7a), where it grows in open habitats on clay and gravelly slopes of Hezar–Masjed Mts. It has been collected from several localities on Hezar–Masjed Mts at 1300–2000 m a. s. l.

Additional specimens examined: **Iran: Khorassan-e Razavi**: Hezar–Masjed Mts., Gosh towards Talqur, 1600–1800 m a. s. l., *Rechinger 5210* (W1956-0003499!, IRAN-11465!); N Chenaran, Boghmej village, toward Emamzade, Hezar–Masjed Mts., 2188 m a. s. l., *Moazzeni*, *Hoseini* and *Mohammadi 46637* (FUMH!); N Mashhad, 1 km from Mareshk towards Balghoor, 1809 m a. s. l., *Moazzeni and Hassanpour 46634* (FUMH!); N Mashhad, 1 km from Mareshk towards Balghoor, 1809 m a. s. l., *Behroozian 46465* (FUMH!); N Mashhad, Kardeh, 1500 m a. s. l., *Joharchi* and *Zangooei 12943* (FUMH!); N Mashhad, Kalat, Khour Mts., 1350 m a. s. l., *Joharchi* and *Zangooei 16821* (FUMH!); Mashhad, Quchan road, Ardak towards Talqur, 1550 m a. s. l., *Sonboli*, *Kanani* and *Gholipour 1101* (MPH!); Heidary Wildlife Refuge, Kelidar village, 2002 m a. s. l., *Atashgahi 7311* (Herbarium of Faculty of Sciences of Ferdowsi University of Mashhad!).

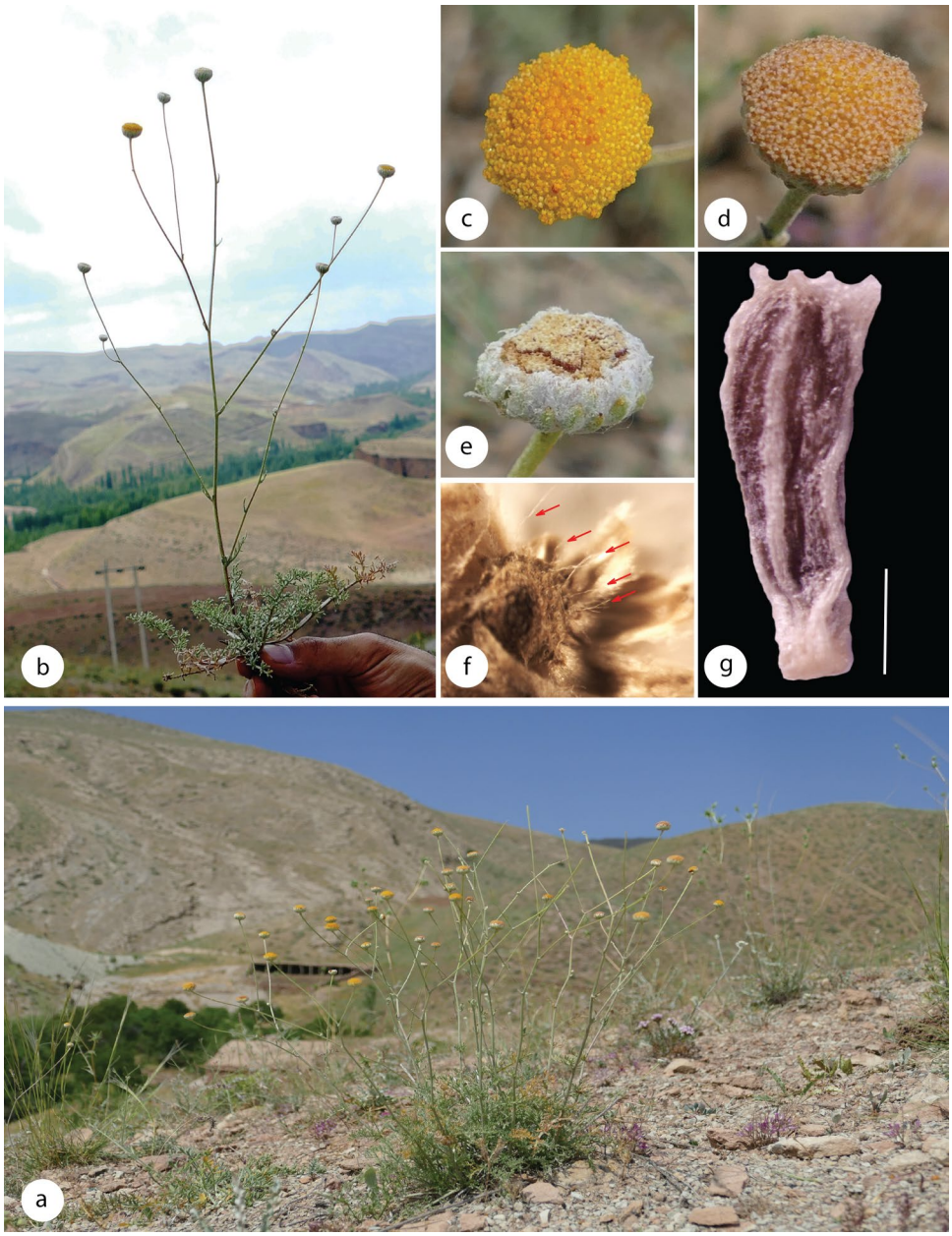

Fig. 4 *Sclerorhachis ferdowsii*; **a, b** habitat ;**c-e** capitula in different stages of maturity; **f** receptacle with paleae highlited by arrows; **g** achene, scale bar = 1 mm

Conservation status: *Sclerorhachis ferdowsii* has been collected from few collections from a small area of 0.5 ha (EOO = 1.819.476 km^2, AOO = 889.035 km^2) of Hezar–Masjed Mts (East of Kopet Dagh range) (Fig. 7a). Therefore, following the IUCN red list criteria (IUCN 2021), the assessment of Endangered (EN) is given.

Reassessment of *Sclerorhachis paropamisica*

This species was originally described as *Pyrethrum paropamisicum* by Krascheninnikov (1946) based on two specimens collected by Korshinsky from Paropamisus Mts. that are deposited in the LE herbarium (Fig. 6; LE00052826!). *Pyrethrum paropamisicum* was later transferred to *Lepidolopsis* by Poljakov (1959), to *Cancrinia* by Tzvelev (1961), to *Tanacetum* by Kovalevskaja (1961), and to *Tanacetopsis* by Kovalevskaja (1972). Finally, Kovalevskaja (1987) accommodated this species in the newly described genus *Sclerorhachis*, which had been coined by Rechinger (1986). However, Rechinger (1986) had previously classified *T. paropamisica* as a synonym of *S. platyrachis*, and

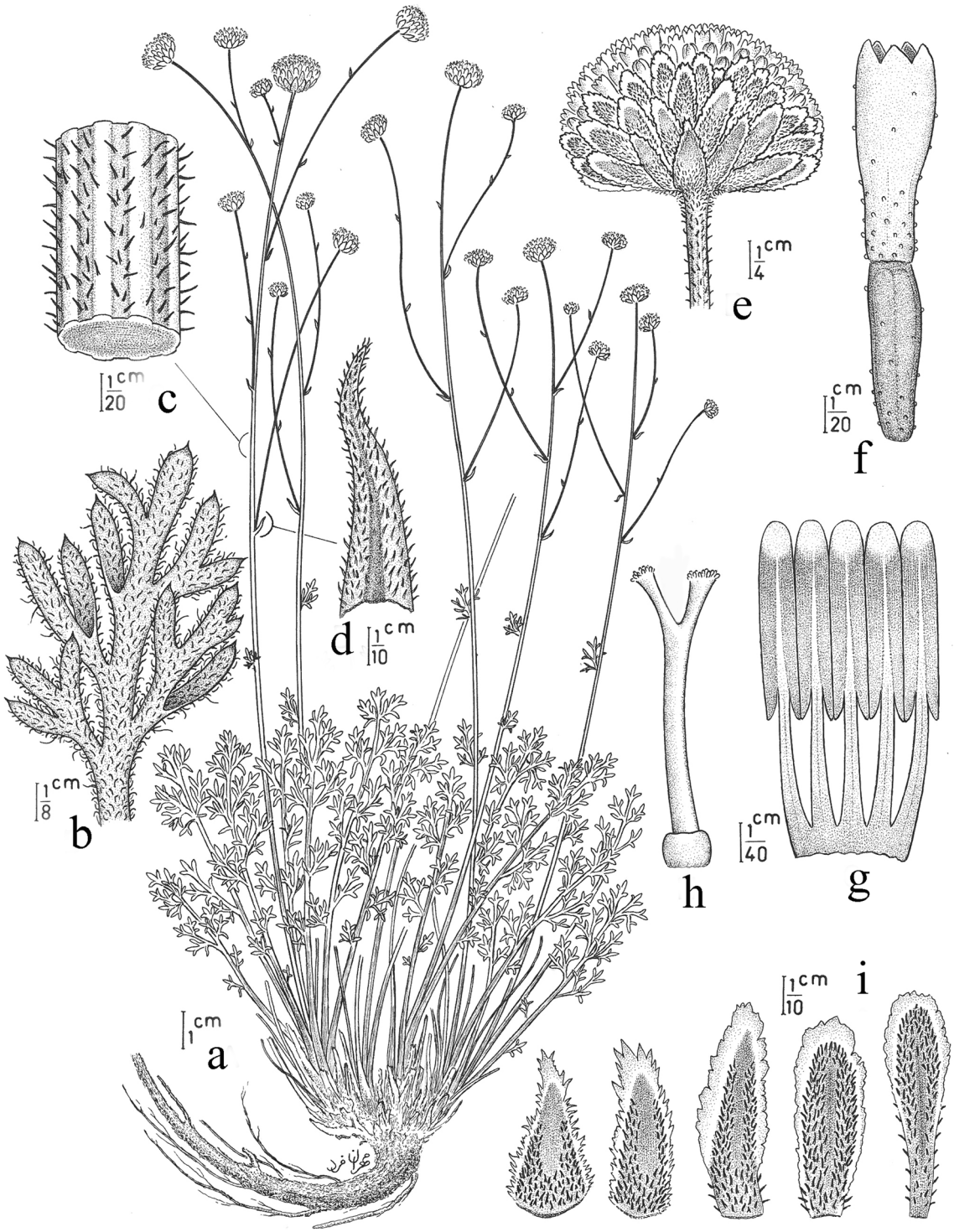

Fig. 5 *Sclerorhachis ferdowsii*; **a** habit; **b** leaf shape; **c** indumentum of stem; **d** bract; **e** inflorescent; **f** floret; **g** stamen; **h** pistil; **i** phyllaries

Mozaffarian (2009) accepted this synonymy for the treatment of the genus in the Flora of Iran.

The five specimens preliminarily ascribed to *S. platyrachis* (collected from the central part of Kopet–Dagh range and Aladagh Mts., see Table 1, under *S. paropamisica*; Figs. 1, 2, clade C1-1) were found being a monophyletic clade sister to *S. ferdowsii* with strong support in our present analysis (Fig. 2, clade C1-1, BS

Fig. 6 Scanned image of the type specimen of *Sclerorhachis paropamisica* (Krasch). Kovalevsk. kept in *LE 2084* (LE00052826)

100, PP 0.1), while the remaining *S. platyrachis* accessions (collected from the Sabzevar and Kashmar–Torbat ranges of the southern border of the KK) formed an independent monophyletic clade (Figs. 1, 2, clade C2). Geographically, the populations of *S. paropamisica* and *S. platyrachis* are at least 100 km apart. Furthermore, morphological data also support this separation with *S. paropamisica* being easily distinguished by having a narrower collar (vs. wider in *S. platyrachis*), a lanate indumentum on the axile of basal leaves (vs. dense indumentum in *S. platyrachis*), narrower petiole sheaths on basal leaves (3–4 mm vs. 5–12 mm in *S. platyrachis*), more sparsely hairy receptacles (vs. densely hairy receptacles), and coronate achene (for more detail see Table 2). Hence, we think that S. *paropamisica* is a distinct species.

Sclerorhachis paropamisica was previously only known from its type locality (*locus classicus*) in the northern highlands of the Paropamis Mountains (Fig. 7c); its presence in NE Iran is not surprising, considering that it was described and previously only known from S Turkmenistan, which borders Iran to the north. Nonetheless, it has been hypothesized that this species may exist in Iran (Tzvelev 1961). Furthermore, it is found in the same range and a comparable phytogeographic environment, thus *S. paropamisica* is still considered endemic to the Kopet Dagh range (Figs. 6, 7c).

Key to species of *Sclerorhachis*

1a Biennial or perennial monocarpic herbs with tap root 2
1b Polycarpic rhizomatous perennials 6
2a Stem glabrescent, mostly purple at the base. Receptacle densely hairy with persistent and thick paleae ..... *S. caulescens*
2b Stem hairy, not purple at the base. Receptacle bearing deciduous paleae 3
3a Collar 2.5–5 cm wide. Basal leaves densely lanate in axils, capitula 12–20 mm in diameter *S. platyrachis*
3b Collar up to 2.5 cm wide. Basal leaves non-lanate in their axils, capitula 6–12 mm in diameter 4
4a Receptacle sparsely hairy. Achenes 2–3.5 mm long, coronate and costate ..... *S. Paropamisica*
4b Receptacle densely hairy. Achenes up to 2.5 mm long, ecoronate with indistinct ribs or punctate..... 5
5a Plants 60–100 cm high. Stem white-puberulent, 5–7 mm in diameter. Leaves 3-pinnatisect. Achenes 2.5 mm long, dark brown with indistinct ribs ..... *S. polysphaera*
5b Plants 40–60 cm high. Stem up to 5 mm in diameter. Leaves 2–3-pinnatisect. Achenes 2 mm long, punctate ..... *S. kjurendaghi*
6a Receptacle distinctly paleate. Achenes 2–2.5 mm long, ecoronate and punctate 7
6b Receptacle sparsely hairy. Achenes 2.5–3 mm long, coronate and costate 8
7a Plants 15–35 cm high. Stem slender, 1–2.5 mm in diameter, glabrescent. Basal leaves 2 (3) pinnatisect. Capitula 5–8 mm in diameter ..... *S. leptoclada*
7b Plants 35–50 cm high. Stem 3–5 mm in diameter. Basal leaves 2–3-pinnatisected. Capitula 10–12 mm in diameter ..... *S. kjurendaghi*
8a Plants 40–60 cm high. Stem 2.5–5 mm in diameter, sparsely leafy. Basal leaves 3-pinnatisect ..... *S. binaludensis*
8b Plants 20–40 cm high. Stem 1.5–2.5 mm in diameter, rather leafless. Basal leaves with 2–3-pinnatisect ..... ***S. ferdowsii***

Table 2 Comparison of morphological characteristics of *Sclerorhachis ferdowsii* with its closest relatives in the *S. platyrachis* species complex

Character	*S. paropamisica*	*S. platyrachis*	*S. ferdowsii*
Height (cm)	70–100	60–150	25–50
Collar width (mm)	17–25	25–30	10–15
Root system	tap root	tap root	rhizome
Indumentum of stem	densely Pubescent	densely Pubescent	laxly Pubescent
Stem diameter (mm)	4–5	6–12	2–3
Basal leaves length (incl. petiole, cm)	10–25	10–30	7–11
Petiole sheath width of basal leaves (mm)	3–4	5–12	2–3
Basal leaves segment shape	linear	linear	narrowly lanceolate/oblong
Basal leaves terminal lobes length (mm)	4–8	3–9	2–4
Basal leaves rachis width (mm)	2–3	2–6	1–2
Capitula diameter (mm)	6–12	13–20	10–12
Capitula length (mm)	5–6	6–9	4–5
Capitula number	30–100	30–100	< 10
Paleae density	sparse	dense	sparse
Achen corona	coronate	non-coronate	coronate
Achene surface vestiture	costate	punctate	costate

Enumeration of species

Sclerorhachis binaludensis Sonboli, Pl. Syst. Evol. 304: 197. 2018. TYPE: Iran, Khorassan-e Razavi, Neyshabur, Garineh Mts., 1900 m a. s. l., 35° 43'N, 53° 02'E, 25 May 2007, *Sonboli 1106* (Holotype: MPH!; Isotype: W!). (Fig. 7a).

General distribution: Iran (Endemic).

Additional specimens examined: **Iran, Khorassan-e Razavi**: Alpine region between Mashhad and Neyshabur, *Bunge s.n.* (G00764196, E00574107 [web!]; E Neyshabur, Garineh Mts., Baghshan village, 1900 m a. s. l., *Faghihnia* and *Zangooei 27768* (FUMH!); N Neyshabur, Mir-Abad Mts., 1558 m a. s. l., *Joharchi* and *Sharghi 45259* (FUMH!); Neyshabur, N mountain of Kharv, 1690 m a. s. l., *Joharchi 44867* (FUMH!); W Mashhad, Binalud Mts., Freskeh, 2000 m a. s. l., *Faghihnia* and *Zangooei 17888* (FUMH!); NW Mashhad, Golmakan, Cheshm-e-Sabz, 1560 m a. s. l., *Ayatollahi* and *Zangooei 13257*, *22598* (FUMH!); Mashhad, Zoshk Mts., *Joharchi 39217* (FUMH!); Ghadamgah, Dizbad village, 1700–2200 m a. s. l., *Mozaffarian 45579* (TARI!); Mashhad, Shah-Taghi, Dizbad, 1800 m a. s. l., *Mozaffarian 48929* (TARI!); Mashhad, N slope of Binalud Mts., Zoshk village, Rudkhan-e-Abdollah, 2100–3000 m a. s. l., *Mozaffarian 48852* (TARI!).

Conservation status: *Sclerorhachis binaludensis* has been collected from a few collections from a small area of 0.5 ha (EOO = 502.643 km^2, AOO = 32.000 km^2) of Binaloud Mts. (Fig. 6). Therefore, following the IUCN red list criteria (IUCN 2021), the assessment of Endangerd (EN) is given.

Sclerorhachis caulescens (Aitch. & Hemsl). Rech.f., Anz. Österr. Akad. Wiss., Math.-Naturwiss. Kl. 105: 243. 1969 ≡ *Anthemis caulescens* Aitch. & Hemsl., Trans. Linn. Soc. London, Bot. 3: 76. 1888. TYPE: Afghanistan, Badghis, Hari-rud valley, 6 June 1885, *Aitchison 610* (Holotype: K000885304; Isotypes: K000885303, BM000945912 [all images online!]). (Fig. 7a).

General distribution: Afghanistan, Iran.

Additional specimens examined: **Afghanistan: Herat:** Cheshme-e-Obeh, 10 km NW Obeh, 1720 m a. s. l., *Podlech* and *Jarmal 29700* (MSB!); 20 km WNW Herat, 1150–1250 m a. s. l., *Freitag 5365* (MSB!); Rabat-e-Mirza, between Herat and Tora-Ghundih, 1250 m a. s. l., *Podlech* and *Jarmal 29539* (MSB!); NW Herat, Koh-e-Zyarat, 1200–1400 m a. s. l., *Podlech* and *Jarmal 29232* (M!); Qala Nau, 1200 m a. s. l., *Köie 3921* (W1968-0000463!); Chisht, 1700 m a. s. l., *Köie 3704* (W1968-0000462!); 45 km S Harat, Mir-Ali pass, on the road to Kandahar, 1650 m a. s. l., *Uotila 16422* (W1976-0001516!); Kija, 1400 m a. s. l., *Köie 3945* (W1958-0000459!); Kouchk, *Lindberg 618* (W1973-0009027!). **Iran**: **Khorassan-e Razavi**: E Torbat-e-Jam, 675 m a. s. l., *Joharchi 34078* (FUMH!); between Mashhad and Sarakhs, SW Mts. of Mazdavand, 950 m a. s. l., *Joharchi* and *Zangooei 16738* (FUMH!); 106 km from Sarakhs to Mashhad, mountains along Kashaf-Rud, 740–750 m a. s. l., *Joharchi 44805* (FUMH!); SW Sarakhs, Salehabad bifurication, 689 m a. s. l., *Joharchi* and *Nasseh 42700* (FUMH!); Torbat-e-Jam, E. Saleh-Abad, Between Saghar-Cheshme and Garmab-olia, 490–500 m a. s. l., *Joharchi* and *Zangooei 34492* (FUMH!); SW Sarakhs, Saleh-Abad bifurication, 790 m a. s. l., *Joharchi* and *Hassanpour 46366* (FUMH!).

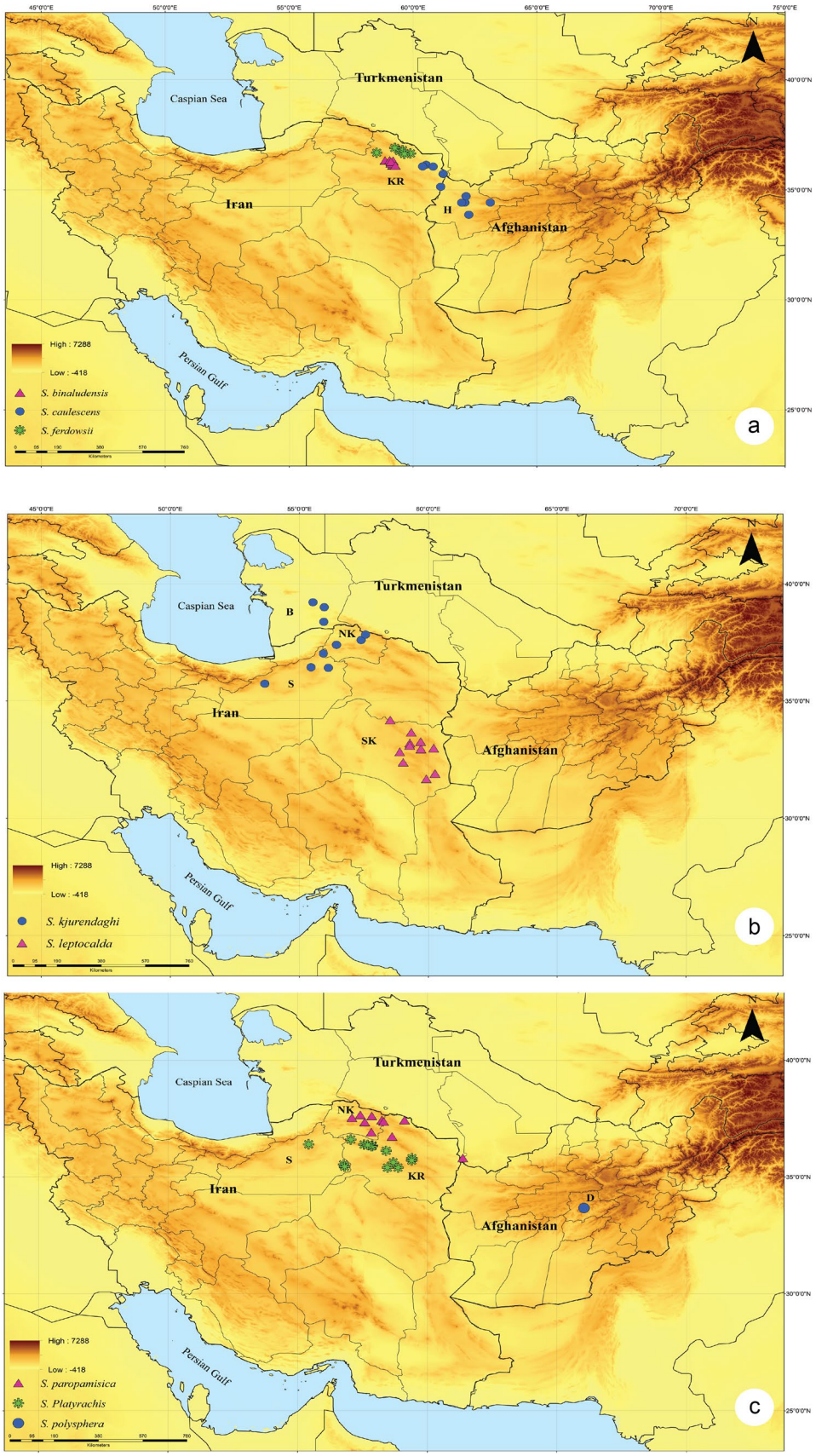

Fig. 7 **a–c** Distribution maps of *Sclerorhachis* species in Iran. **a** *Sclerorhachis binaludensis* (red triangles), *S. caulescens* (blue dots), *S. ferdowsii* (green stars); **b** *S. kjurendaghi* (blue dots), *S. leptoclada* (red triangles); **c** *S. paropamisica* (red triangles), *S. platyrachis* (green stars), *S. polysphera* (blue dots). (Color figure online)

Conservation status: ***Sclerorhachis caulescens*** has been collected from an area of 19.5 ha (EOO = 19.380.715 km^2, AOO = 8.585.994 km^2) from several collections (Fig. 7a). Therefore, following the IUCN red list criteria (IUCN 2021), the assessment of Vulnerable (VU) is given.

Sclerorhachis ferdowsii Hassanpour, Moazzeni & Sonboli TYPE: Iran, Khorassan-e Razavi, N Mashhad, 1 km from Mareshk to Balghour, 1809 m a. s. l., *Moazzeni* and *Jafari 46635* (FUMH!; isotype: FUMH!). (Figs. 4, 5 and 7a).

General distribution: Iran (Endemic).

Additional specimens examined: **Iran: Khorassan-e Razavi**: Hezar–Masjed Mts., Gosh towards Talqur, 1600–1800 m a. s. l., *Rechinger 5210* (W1956-0003499!, IRAN-11465!); N Mashhad, Kardeh, 1500 m a. s. l., *Joharchi* and *Zangooei 12943* (FUMH!); N Mashhad, 1 km from Mareshk towards Balghoor, 1809 m a. s. l., *Moazzeni and Hassanpour 46634* (FUMH!); N Mashhad, 1 km from Mareshk towards Balghoor, 1809 m a. s. l., *Behroozian 46465* (FUMH!); N Mashhad, Kalat, Khour Mts.1350 m a. s. l., *Joharchi* and *Zangooei 16821* (FUMH!); Mashhad, Quchan road, Ardak towards Talqur, 1550 m a. s. l., *Sonboli*, *Kanani* and *Gholipour* 1101 (MPH!); Heidary Wildlife Refuge, Kelidar village, 2002 m a. s. l., *Atashgahi 7311* (Herbarium of Faculty of Science of Ferdowsi University of Mashhad).

Conservation status: *Sclerorhachis ferdowsii* has been collected from few collections from a small area of 1.8 ha (EOO = 1.819.476 km^2, AOO = 889.035 km^2) of Hezar–Masjed Mts. (Southern part of khorassan-Kopet Dagh province). (Fig. 6a). Therefore, following the IUCN red list criteria (IUCN 2021) it is given the assessment of Endangered (EN).

Sclerorhachis kjurendaghi (Kurbanov) Kovalevsk., in Novosti Sist. Vyssh. Rast. 24: 169. 1987. ≡ *Tanacetopsis kjurendaghi* Kurbanov., Bot. Zhurn. (Moscow & Leningrad) 69: 692. 1984. 7 TYPE: Turkmenistan, Kjurendagh mountain, Tragoj, 3 km to NE Tragoj, on the clay slopes of palaeogene (relating to or denoting the earlier division of the Tertiary period), 9 May 1982 fl., *Kurbanov s.n.* (LE0052825 [web!]). (Fig. 7b).

General distribution: Iran, Turkmenistan.

Additional specimens examined: **Iran**: **North Khorassan**: NE Bojnurd, on the road to Gifan, 8 km from Petroshimi, 900–942 m a. s. l., *Memariani* and *Zangooei 38958* (FUMH!); W Bojnurd, Ghoorkhud Protected Area, 1590 m a. s. l., *Joharchi* and *Memariani 45030* (FUMH!); W Bojnurd, Ghoorkhud Protected Area, 1600–1700 m a. s. l., *Memariani* and *Arjmandi 44364* (FUMH!); W Bojnurd, Ghoorkhud Protected Area, 1534 m a. s. l., *Memariani* and *Arjmandi 43810* (FUMH!); W Jajarm, 3-way junction Hossein-Abad, Darq and Mayamey, 1330 m a. s. l., *Akhani* and *Joharchi 35560* (FUMH!); 15 km Gifan from Bojnurd, Sork village, 1000 m a. s. l., *Assadi* and *Maassoumi 50159* (TARI!). **Seman**: E Shahrud, Turan Protected Area, between Miandasht and Abbas-Abad, 25 km W Abbas-Abad, 1245 m a. s. l., *Joharchi* and *Memariani 46122* (FUMH!); Semnan to Damghan, Gardan-e-Ahuvan, *Sonboli 2209* (MPH!); Turan Protected Area, Delbar, N. slope of Kuh-e-Moru, 1140 m a. s. l., *Mozaffarian 83670* (TARI!); 34 km E Shahrud road to Sabzevar, 1450 m a. s. l., *Assadi* and *Mozaffarian 21206* (TARI!). **Turkmenistan:** Kjurendagh montain, Tragoj, 3 km to NE Tragoj, on the clay slopes of palaeogene, 23 June 1981 fl., *D. Kurbanov s.n.* (paratype, LE0052824 [web!]).

Conservation status: *Sclerorhachis kjurendaghi* has been collected from several collections from an area of 62 ha (EOO = 62,169.813 km^2, AOO = 17,714.702 km^2) of N, NW and W of Iranian and Turkeman Kopet Dagh Mts, and also its distribution range widened a little to the west in Seman province. (Fig. 6). Therefore, following the IUCN red list criteria (IUCN 2021) it is given the assessment of Least Concern (LC).

Note: The populations corresponding to *S. kjurendaghi* from west of KK showed high intraspecific variation (e.g., both tap and rhizome root systems present, high variation observed in terms of number of capitula, plant sizes, and collar width). This high morphological variation might be due to hybridization that causes intermediate or even differentiable to separate species (new species) that would need additional sequence data for corroboration.

Sclerorhachis leptoclada Rech.f., Pl. Syst. Evol. 138: 297. 1981. TYPE: Persia orientalis [Iran], prov. Khorasan [South Khorassan]: In collibus argillososchistosis prope Dorokhsh, 33° 12'N, 59° 38'E, ab Assadabad 40 km occidentem versus, ad bifurcationem viae versus Qayen ducentis, 1900 m a. s. l., 3 June 1977, *K.H. Rechinger 56215* (G00301825 [web!], isotype W19820007890!). (Fig. 7b).

General distribution: Iran (Endemic).

Additional specimens examined: **Iran**: **South Khorassan:** Steppe areas in 25 km N mountains of Birjand, 2000 m a. s. l., *Soják 8372* (W 1986–0005935!); on the road Gonabad to Ferdows, Kalat Mts., 1800 m a. s. l., *Ayatollahi* and *Zangooei 15186* (FUMH!); Gonabad, Kalat Mts., 1800 m a. s. l., *Ayatollahi* and *Zangooei 15207* (FUMH!); N Birjand, N mountain between Khong and Rubokht villages, 1925 m a. s. l., *Joharchi 45005* (FUMH!); E Qaen, 4 km from Vorezg to Vorazq, 1600 m a. s. l., *Rafiei* and *Hosseinzadeh 30808* (FUMH!); 30 km N Birjand, 1950 m a. s. l., *Ayatollahi* and *Zangooei 12184* (FUMH!); NE Birjand, Mask Mts., 2100 m a. s. l., *Faghihnia* and *Zangooei 30322* (FUMH!); Birjand, Sar-chah, 1900 m a. s. l., *Faghihnia* and *Zangooei 30053* (FUMH!); Birjand, Amin-Abad, 1900 m a. s. l., *Faghihnia* and *Zangooei 30340* (FUMH!); E Birjand, Gazik Mts., 1400–1500 m a. s. l., *Joharchi* and *Zangooei 17272* (FUMH!); NW Nehbandan, Ghadamgah village, 1700 m a. s. l., *Hojjat* and *Zangooei 29852* (FUMH!); NW Birjand, Noghand, 1950 m a. s. l., *Zangooei* and *Hosseinin-zadeh 24213* (FUMH!); Nehbandan, Shusf, between

Afzal-Abad and Sigarud, 1656 m a. s. l., *Joharchi* and *Zangooei 36254* (FUMH!).

Conservation status: *Sclerorhachis leptoclada* has been collected from several collections of 1.8 ha (EOO = 22,315.020 km^2, AOO = 9,521.182 km^2) of South Khorasan province. (Fig. 6). Furthermore, this species is commonly harvested by local people in South Khorassan and is used by indigenous people as a medicinal and food plant (Mohammadi et al. 2020). Therefore, following the IUCN red list criteria (IUCN 2021) the assessment of Near Threatened (NT) is given.

Sclerorhachis paropamisica (Krasch). Kovalevsk., Novosti Sist. Vyssh. Rast. 24: 168. 1987. ≡ *Pyrethrum paropamisicum* Krasch., Bot. Mater. Gerb. Bot. Inst. Komarova Akad. Nauk S.S.S.R. 9: 166. 1946. ≡ *Lepidolopsis paropamisica* (Krasch.) Poljakov, Bot. Mater. Gerb. Bot. Inst. Komarova Akad. Nauk S.S.S.R. 19: 376. 1959. ≡ *Cancrinia paropamisica* (Krasch.) Tzvelev, Fl. URSS 26: 310. 1961. ≡ *Tanacetum paropamisicum* (Krasch.) Kovalevsk., Bot. Mater. Gerb. Inst. Bot. Zool. Akad. Nauk Uzbeksk. S.S.R. 16: 30. 1961. ≡ *Tanacetopsis paropamisica* (Krasch.) Kovalevsk., Novosti Sist. Vyssh. Rast. 9: 270. 1972. TYPE: Asia Media, Turcomania [Turkemenistan], mons Paropamis, in angustiis Nardvan-li [Nerdevanli spring] prope locum Akar-czeschme [Akarchesme] dictum, in decliviis. 6 May 1895, *Korshinsky 2084* (LE00052826 [web!]; isotype: LE00052827 [web!]). (Figs. 6, 7c).

General distribution: Iran, Turkmenistan, probably Afghanistan.

Additional specimens examined: **Iran: North Khorassan**: Shah–Jahan Protected Area, S slopes of rocky hills N Hessari, 1400–1600 m a. s. l., *Rechinger 53623* (W1986-00005381!); Shirvan, Lujeli, 1400–1600 m a. s. l., *Djavadi* and *Sadeghi 11458* (IRAN!); Quchan, Faruj to Kohne-Owqaz, Qale-Safa Mts. 1750 m a. s. l., *Faghihnia* and *Zangooei 29325* (FUMH!); SE Bojnurd, 6 km from Nodeh to Esfidan, 1500 m a. s. l., *Raafei* and *Zangooei 31548* (FUMH!); N Bojnurd, 1–2 km S. Ghezlghan towards Bojnurd, 950–1000 m a. s. l., *Memariani* and *Zangooei 42949* (FUMH!); N Faruj, 1400 m a. s. l., *Faghihnia* and *Zangooei 31252* (FUMH!); Bojnurd, S Badranloo, 1900 m a. s. l., *Zangooei* and *Hossein–zadeh 24447* (FUMH!); **Khorassan-e Razavi**: Dargaz, Zarrin-Kuh Protected Area, *Amiri 45689* (FUMH!).

Conservation status: *Sclerorhachis paropamisica* has been collected from an area of 377 ha (EOO = 377,665.158 km^2, AOO = 20.000.000 km^2) of the Iranian Kopet–Dagh and Paropamis Mts. (Fig. 6). Therefore, following the IUCN red list criteria (IUCN 2021), the assessment of Less concern (LC) is given.

Sclerorhachis platyrachis (Boiss.) Podlech ex Rech.f., Fl. Iranica 158: 47. 1986. ≡ *Pyrethrum platyrachis* Boiss., Fl. Orient 3: 356. 1875. ≡ *Chrysanthemum platyrachis* (Boiss.) Parsa, Fl. Iran 3: 274. 1949. ≡ *Cancrinia platyrachis* (Boiss.) Tzvelev, Fl. URSS 26: 311. 1961. ≡ *Tanacetum platyrachis* (Boiss.) Kovalevsk., Bot. Mater. Gerb. Inst. Bot. Zool. Akad. Nauk Uzbeksk. S.S.R. 16: 23. 1961. ≡ *Tanacetopsis platyrachis* (Boiss.) Kovalevsk., Novosti Sist. Vyssh. Rast. 9: 270. 1972. TYPE: Iter persicum. [Iran] "pr. Sebsewar [Sabzevar], Chorassan [Khorassan-e Razavi], inter Schahrud et Nischapur. Juni 1858", [*Bunge*] *99* (lectotype designated by Hassanpour et al. (2018): Herbar. Bungeanum G00764721!; isotypes: P00760288, P00760289, P00760290). (Fig. 7c).

= *Sclerorhahis rechingeri* Iranshahr, Pl. Syst. Evol. 132: 149. 1979. TYPE: Iran. Khorasan [Khorassan-e Razavi]: in montibus serpentinieis 17–20 km E Sabzevar versus Soltanabad, 1150–1400 m a. s. l., *Rechinger 53702* (W19860005372; isotypes: B100097182, E00413517, GZU-Rechinger 000272962, K000885302, MSB002218, M0030155).

General distribution: Iran (Endemic).

Additional specimens examined: **Iran: Khorassan-e Razavi**: 17–21 km from Sabzevar towards Soltan-Abad, serpentine mountain, 1150–1400 m a. s. l., *Rechinger 53702* (W1986-0005372!; Isotype of *S. rechingeri*); 80 km N Torbat-e-Heidariyeh, 1100 m a. s. l., *Rajamand* and *Bazargan 32022* (W!); between Mashhad and Torbat-e-Heidariyeh, Robat-Sefid, 1600–1700 m a. s. l., *Rechinger 55881* (W1982-0,007,760!); 20 km N Sabzevar, Joghatai Mts., 1750 m a. s. l., *Rechinger 53,674* (W1986-0,005,373!); between Mashhad and Torbat-e-Heidariyeh, Robat-Sefid, 1800–2000 m a. s. l., *Renz* and *Runemark 55,984* (W1982-0,007,735!); serpentine Mts. of Robat-Sefid, 1800–2000 m a. s. l., *Rechinger 4445* (W1986-0003498!; 11463-IRAN!); serpentine Mts. in E of Sabzevar, *Rechinger 1311* and *5275* (W1951-00011823!, W1968-000113497!; 11466-IRAN!); Between Abbas-Abad and Mashhad, 1000–1500 m a. s. l., *Schmid 6100* (W1959-00022198!); 82–90 km S Mashhad = 70 km N Torbat-e-Heidariyeh, serpentin Mts. of Robat-Safid, 1520 m a. s. l., *Rechinger 51325* (W1986-0005371!); Torbat-e-Heydariyeh, on the road to Robat-Sefid, 1720 m a. s. l., *Hassanpour 2363* (MPH!); Sabzevar on the road to Soltan-Abad, Baghjar village, 1470 m a. s. l., *Hassanpour 2364* (MPH!); 82–90 km of Mashhad, Between Kafar-Ghale and Robat-Safid, 1520 m a. s. l., *Rechinger 11457* (IRAN!); Sabzevar towards Neyshabur, 15–20 km E Sabzevar, 1150 m a. s. l., *Termeh 11460* (IRAN!); 20 km NE Sabzevar, 1330 m a. s. l., *Pabot 11462* (IRAN!); 96 km from Mashhad on the road to Torbat-e-Heydariyeh, Robat-Sefid, 1800–2000 m a. s. l., *Assadi* and *Maassoumi 21296* (TARI!); 90 km from Mashhad on the road to Torbat-e-Heydariyeh, 1700 m a. s. l., *Assadi* and

Maassoumi 21286 (TARI!); N Robat-Sefid, 1700–2000 m a. s. l., *Runemark* and *Sardabi 23,567* (TARI!); 20 km from Sabzevar to Neyshabur, 1300 m a. s. l., *Assadi* and *Mozaffarian 35,390* (TARI!); 15 km from Sabzevar to Esfaryen (old road), 1470 m, *Mozaffarian 81243* (TARI!); 50 km NNE Kashmar, kuh-e-Bezgh, 1900 m a. s. l., *Assadi* and *Mozaffarian 35777* (TARI!); 14 km from Kashmar to Neyshabur, 1400–1500 m a. s. l., *Assadi* and *Mozaffarian 35607* (TARI!); Sabzevar, 70 km Neyshabur road, 1180 m a. s. l., *Rajamand* and *Bazargan 32,097* (TARI!); N Torbat-e-Heydariyeh, Garmab, 1669 m a. s. l., *Faghihnia 34,714* (FUMH!); Torbat-e-Heydariyeh, 6 km to Rud-Maajan, 1600 m a. s. l., *Ayatollahi* and *Zangooei 14556* (FUMH!); near Torbat-e-Heydarieh, Assad-Abad pass, 1600 m a. s. l., *Ayatollahi* and *Zangooei 14650* (FUMH!). **Semnan province**: Turan Protected Area, 10 km from Talkhab to Garmab, 1400 m a. s. l., *Freitag* and *Jadidi 29056*, *29059* (TARI!); Turan Protected Area, higher parts of Kuh-e-Peyghambar, 2000–2200 m a. s. l., *Freitag 13754* (TARI!).

Conservation status: *Sclerorhachis platyrachis* has been collected from several collections from an area of 19.8 ha (EOO = 19,892.381 km^2, AOO = 5,766.485 km^2) of western ranges of Kopet–Dagh Mts. (Fig. 6). Therefore, following the IUCN red list criteria (IUCN 2021), the assessment of Vulnerable (VU) is given.

***Sclerorhachis polysphaera* Rech.f.** in Anz. Österr. Akad. Wiss., Math.-Naturwiss. Kl. 105: 244. 1969. TYPE: Afghanistan. Deh Kundi. In saxosis 10 km W Shahrestan, 33°40'N 66°35'E, versus Deh Kundi, 34° 10'N, 66° 07' E, 2200 m a. s. l., *Rechinger 36811* (W1969-0013830!, isotypes: E00413516 [web!], E00574111 [web!], G00301824 [web!], US00125029 [web!], M0030157!, MO-176949 [web!], K000885301 [web!]). (Fig. 7c).

General distribution: Afghanistan.

Additional specimens examined: **Afghanistan:** Deh Kundi, 10 km W of Shahrestan towards Deh Kundi, 33° 40´ N, 66° 07´ E, 2200 m a. s. l., *Rehinger 36811* (W1969-0013830!, M!).

Conservation status: *Sclerorhachis polysphaera* is known only from the type locality. Its conservation status is given Data Deficient (DD.) according to the IUCN (2021) criteria.

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Author contributions SH: Supervising the study, specimen study, plant collection, laboratory procedures, molecular analyses, and manuscript preparation. HM: Supervising the study, specimen study, plant collection, laboratory procedures, molecular analyses, and manuscript preparation. AS: providing some references, manuscript revision. SSH: laboratory procedures, manuscript revision. AP: molecular analyses, manuscript revision. MRJ: Specimen study, manuscript revision. CO: providing some references, manuscript revision.

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Data availability All DNA sequences are publicly available through Genbank. All other data included in the manuscript.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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