

ARTICLE

Pollen morphology of *Senecio* L. and *Iranecio* B. Nord. (Asteraceae: Senecioneae) in Iran

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ABSTRACT The genus *Senecio* L. is one of the largest genera in the family Asteraceae. The number of taxa included in this genus is 1250. Pollen morphology has proved useful in the systematics of Asteraceae as well as in that of some of its genera and species. The pollen morphology of 16 taxa of the genus *Senecio* and *Iranecio* was investigated in detail by scanning electron microscopy (SEM). Examination showed pollen grains to be isopolar and radiosymmetric, prolate spheroidal. The close relationships are observed between the species of the section *Quadridentati* and the genus *Iranecio*. The species of the section *Jacobaea* showed a palynological overlap with the section *Senecio*. The results indicate that the palynological characters of the genus *Senecio* are valuable for taxonomic applications and are useful for classification.

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KEY WORDS

Iranecio
palynological characters
pollen
scanning electron microscopy
Senecio

Introduction

The Asteraceae is the most numerous family of the Angiosperms, with approximately 23.600 species (Montes and Murray 2015). Senecioneae is one of the largest tribe in the family with more than 3000 species in 150 genera (Pelser et al. 2007), classified into three subtribes; Blennospermatinae, Senecioninae, and Tussilaginatae. Approximately one-third of Senecioneae species are placed in the genus *Senecio*, making it one of the largest genera of flowering plants (Willis 1918).

Nordenstam (1989) transferred some species of *Senecio* into the genus *Iranecio* B. Nord. and introduced 4 sections and 17 taxa of this genus in Iran. The genus *Senecio* after Nordenstam (1989) draft of Flora Iranica has been subject of several studies; partly circumscription of the genus has been changed. Jeffrey (1992) based on anatomical characteristics of what transferred species that belonged to *Senecio* sect. *Quadridentati* Boiss. to the genus *Iranecio*. Also, Pelser et al. (2006) and Nordenstam (2006) based on molecular systematic studies regarded the section *Jacobaea* (Mill.) Dumort. as a distinct genus.

Pollen morphology has been proved to be useful in the systematics of the Asteraceae family as well as that of some

of its genera and species (Moore et al. 1991). Osman (2011) defined the *Senecio* pollen type for the tribe Senecioneae as tricolpororate. Montes and Murray (2015) showed the presence of the mesoaperture in the *Senecio bergii* Hieron pollen contributes to the general knowledge of the *Senecio* pollen type. Moreover, it will be of importance in the taxonomic delimitation of species in this genus.

The present study aims to study general pollen morphological characters and to assess their taxonomical value in separation of taxa in different level.

Materials and Methods

We employed SEM in order, to conduct palynological studies of 14 species of the genus *Senecio* belonging to four sections (Nordenstam 1989):

a) *Crociseris* – *S. pseudo-orientalis* Schischk., *S. dorii-formis* subsp. *orientalis* (Fenzl) V. A. Matthews., *S. paulsenii* subsp. *khorsanicus* (Rech.f. & Aellen) B.Nord.

b) *Quadridentati* – *S. taraxacifolius* (M. B.) DC., *S. davidisii* Matthews., *S. lipskyi* Lomak.

c) *Jacobaea* – *S. mollis* Willd., *S. erucifolius* subsp. *grandidentatus* (Ledeb.) V.E.A vet.

d) *Senecio* – *S. glaucus* L., *S. vulgaris* L., *S. breviflorus* (Kadereit) Greuter, *S. leucanthemifolius* subsp. *vernalis* (Waldst. & Kit.) Greuter, *S. iranicus* B. Nord., *S. kotschyanus* Boiss.

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Table 1. List of studied taxa of *Senecio* and *Iranecio* (Asteraceae) with localities and voucher numbers.

Section/Species	Locality	N	E	Alt (m)	Voucher number
<i>Senecio</i>					
<i>S. breviflorus</i>	Karaj, Azimieh	51.00	35.50	1469	HSBU-4369
<i>S. kotschyanus</i>	Kerman, Gughar village	57.14	29.26	3059	TUH-23455
<i>S. iranicus</i>	Mazandaran, Polur	52.02	35.51	4300	IRAN-53397
<i>S. vulgaris</i>	Tehran, Velenjak	51.23	35.48	1758	HSBU-4372
<i>S. glaucus</i>	Kashan, Abyaneh	51.35	33.35	2216	HSBU-4373
<i>S. leucanthemifolius</i> subsp. <i>vernalis</i>	Mazandaran, Alasht	52.50	36.04	1684	HSBU-4375
<i>Crociseris</i>					
<i>S. paulsenii</i> subsp. <i>khorsanicus</i>	Mazandaran, Balade to Noor	51.55	36.24	919	TUH- 38605
<i>S. pseudo-orientalis</i>	West Azarbaijan, Shahindej	46.41	36.32	1799	TARI-69861
<i>S. doriiformis</i> subsp. <i>orientalis</i>	Kordestan, Paveh	46.21	35.03	2600	TUH-7980
<i>Quadridentati</i>					
<i>S. taraxacifolius</i>	East Azarbaijan, Bostanabad	46.41	37.54	3700	TARI-48593
<i>S. lipskyi</i>	East Azarbaijan, Mishodagh	45.47	38.13	1911	TUH-11951
<i>S. davisii</i>	West Azarbaijan, Silvana	73.57	40.48	35	TARI-69903
<i>Jacobaea</i>					
<i>S. erucifolius</i> subsp. <i>grandidentatus</i>	Golestan, Gorgan	55.39	37.21	531	IRAN-35506
<i>S. mollis</i>	Kordestan, Sanandaj	47.05	35.39	2056	TUH-40393
<i>Iranecio</i>					
<i>I. elbursensis</i>	Tehran, Chlous road, Gachsar, Dizin	52.12	39.39	1856	TUH-6981
<i>I. oligolepis</i>	Mazandaran, Rineh, kuh-e Damavand	49.41	36.02	1700	IRAN-10430

Table 2. Palynological characters of studied taxa. P: polar axis; E: equatorial diameter; P/E: ratio of polar axis to equatorial diameter; SL: spine length; SW: spine width; SN: spine number; PN: perforation number; ISD: interspine distance; IPD: interperforation distance; PP/SL: perforated part/spine length. Units for quantitative characters.

Taxa	P	E	P/E	SL	SW	SN	PN	ISD	IPD	PP/SL
<i>S. breviflorus</i>	26.26 ± 1.70	23.21 ± 1.25	1.13 ± 0.74	2.14 ± 0.04	2.30 ± 0.08	8	20	1.06 ± 2.34	0.28 ± 1.12	1
<i>S. kotschyanus</i>	24.91 ± 1.23	22.40 ± 1.19	1.11 ± 0.54	2.85 ± 0.54	3.00 ± 0.05	8	30	0.85 ± 2.11	0.28 ± 1.47	1
<i>S. iranicus</i>	22.35 ± 1.55	20.29 ± 1.28	1.11 ± 0.56	3.00 ± 0.11	2.65 ± 0.09	8	25	1.05 ± 2.24	0.26 ± 1.24	1
<i>S. vulgaris</i>	25.33 ± 1.27	22.42 ± 1.30	1.12 ± 0.67	3.72 ± 0.03	3.30 ± 0.10	8	20	1.17 ± 2.19	0.30 ± 1.30	1
<i>S. glaucus</i>	22.80 ± 1.34	21.00 ± 1.09	1.08 ± 0.49	3.08 ± 0.10	2.51 ± 0.08	8	35	1.05 ± 2.43	0.28 ± 1.62	1
<i>S. leucanthemifolius</i>	19.95 ± 1.43	18.03 ± 1.21	1.10 ± 0.33	2.65 ± 0.13	1.80 ± 0.11	8	20	1.18 ± 2.27	0.28 ± 1.52	1
<i>S. paulsenii</i>	30.81 ± 1.63	28.52 ± 1.12	1.08 ± 0.52	3.03 ± 0.16	2.55 ± 0.17	6	5	1.17 ± 2.49	0.50 ± 1.39	2
<i>S. pseudo-orientalis</i>	30.34 ± 1.82	27.60 ± 1.22	1.09 ± 0.67	3.42 ± 0.11	2.47 ± 0.21	6	15	1.47 ± 2.31	0.34 ± 1.45	2
<i>S. doriiformis</i>	27.63 ± 1.72	25.20 ± 1.39	1.09 ± 0.82	3.43 ± 0.06	3.10 ± 0.16	6	15	1.37 ± 2.10	0.37 ± 1.19	2
<i>S. taraxacifolius</i>	32.50 ± 1.18	30.10 ± 1.09	1.07 ± 0.71	3.00 ± 0.16	3.14 ± 0.05	4	5	2.4 ± 2.92	0.32 ± 1.13	2
<i>S. lipskyi</i>	33.61 ± 1.39	29.30 ± 1.73	1.14 ± 0.84	2.85 ± 0.19	2.93 ± 0.25	4	12	2.27 ± 3.20	0.30 ± 1.37	2
<i>S. davisii</i>	36.82 ± 1.90	33.12 ± 2.04	1.11 ± 0.77	3.20 ± 0.23	3.30 ± 0.09	4	5	2.43 ± 2.89	0.36 ± 1.41	2
<i>S. erucifolius</i>	24.00 ± 1.13	22.30 ± 1.95	1.07 ± 0.12	2.36 ± 0.17	2.00 ± 0.10	7	30	1.11 ± 2.68	0.30 ± 2.01	1
<i>S. mollis</i>	25.20 ± 1.22	23.71 ± 1.87	1.06 ± 0.10	2.42 ± 0.11	2.30 ± 0.22	7	30	1.16 ± 3.42	0.33 ± 1.87	1
<i>I. elbursensis</i>	35.00 ± 2.66	32.10 ± 2.97	1.09 ± 0.37	2.90 ± 0.21	3.00 ± 0.29	4	10	2.45 ± 2.21	0.35 ± 2.31	2
<i>I. oligolepis</i>	31.50 ± 3.01	28.91 ± 2.55	1.08 ± 0.09	3.00 ± 0.07	3.10 ± 0.32	4	5	2.40 ± 2.75	0.40 ± 1.97	2

In this study four species of the genus *Senecio* (*S. kotschyanus*, *S. iranicus*, and *S. vulcanicus*) are endemic to Iran.

We also studied two species of the genus *Iranecio*: *I. elbursensis* and *I. oligolepis* are endemic to Iran. Voucher

specimens are listed in Table 1 and deposited in the Central Herbarium of Tehran University (TUH), Herbarium of the Iranian Research Institute of Plant Protection (IRAN), the Herbarium of Shahid Beheshti University (HSBU) and Research Institute of Forests and Rangelands Tehran (TARI).

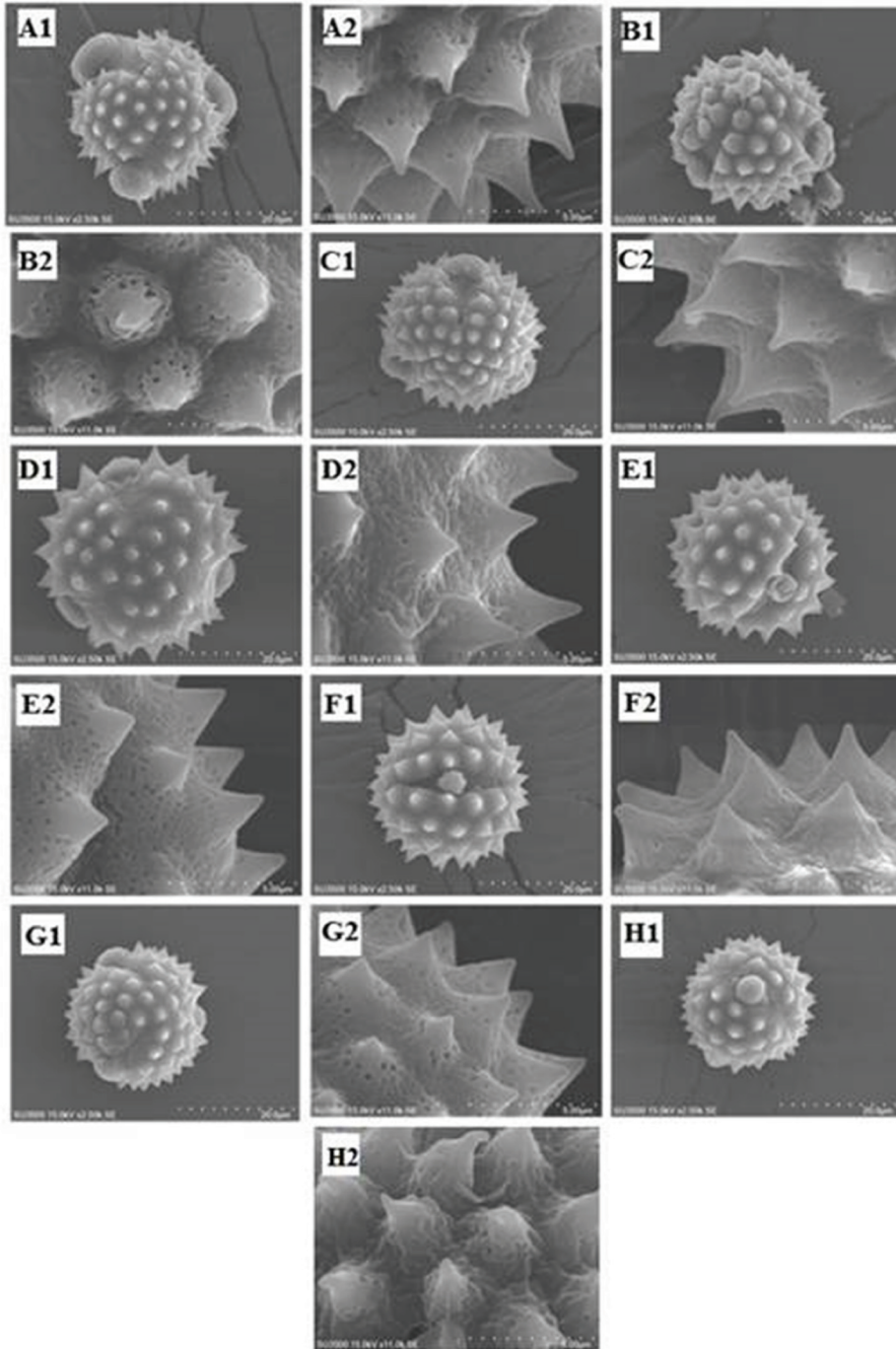


Figure 1. SEM photographs show pollen grain morphology of the studied species of genus *Senecio* L. (Asteraceae). A1-A2: *S. pseudo-orientalis*; B1-B2: *S. doriiformis* subsp. *orientalis*; C1-C2: *S. paulsenii* subsp. *khorsanicus*; D1-D2: *S. davisii*; E1-E2: *S. lipskyi*; F1-F2: *S. taraxacifolius*; G1-G2: *S. mollis*; H1-H2: *S. erucifolius* subsp. *grandidentatus*. The first photographs represent general view of the pollen grains and the second ones show the details of the surface ornamentation.

The study using scanning electron microscopy (SEM) was performed on 16 taxa representing 14 species of the genus *Senecio* and 2 species of the genus *Iranecio* (Table 1). Palynological characters were randomly measured by using

minimum 50 pollen grains of 15 individuals belong to 3 populations and the means were used in analyses. We studied a total of 10 quantitative and qualitative pollen characters (Table 2). The specimens were examined and photographed

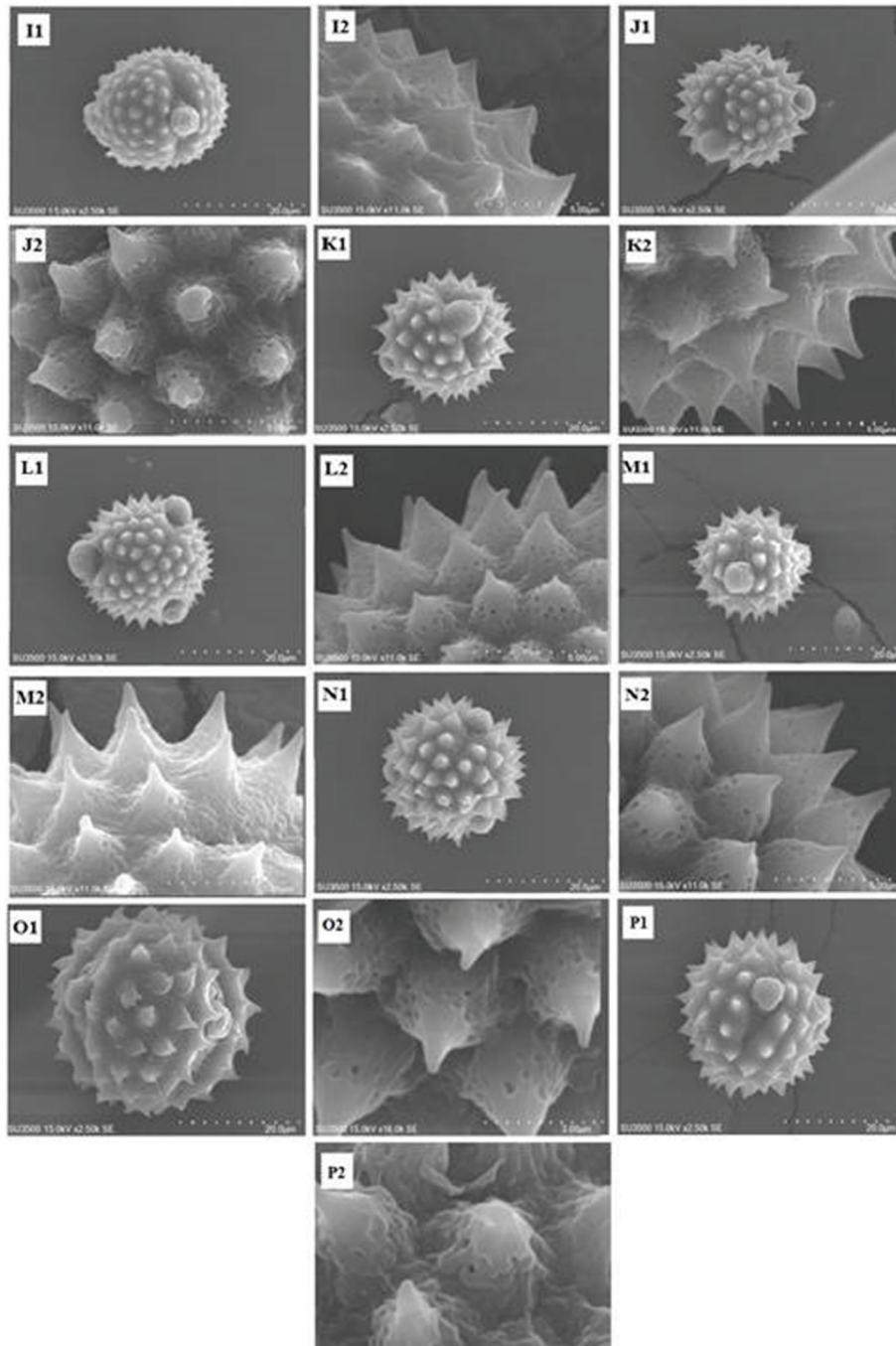


Figure 2. SEM photographs show pollen grain morphology of the studied species of genus *Senecio* L. and *Iranecio* L. (Asteraceae). I1-I2: *S. breviflorus*; J1-J2: *S. glaucus*; K1-K2: *S. iranicus*; L1-L2: *S. kotschyanus*; M1-M2: *S. leucanthemifolius* subsp. *vernalis*; N1-N2: *S. vulgaris*; O1-O2: *I. elbursensis*; P1-P2: *I. oligolepis*. The first photographs represent general view of the pollen grains and the second ones show the details of the surface ornamentation.

with a scanning electron microscope (SU3500; HITACHI, Japan) at an accelerating voltage of 20 kV. The terminology follows mainly Erdtman (1952).

Statistical analyses including PCA were performed using PAST ver. 2.17 software for plotting variation among populations and species (Hammer et al. 2009).

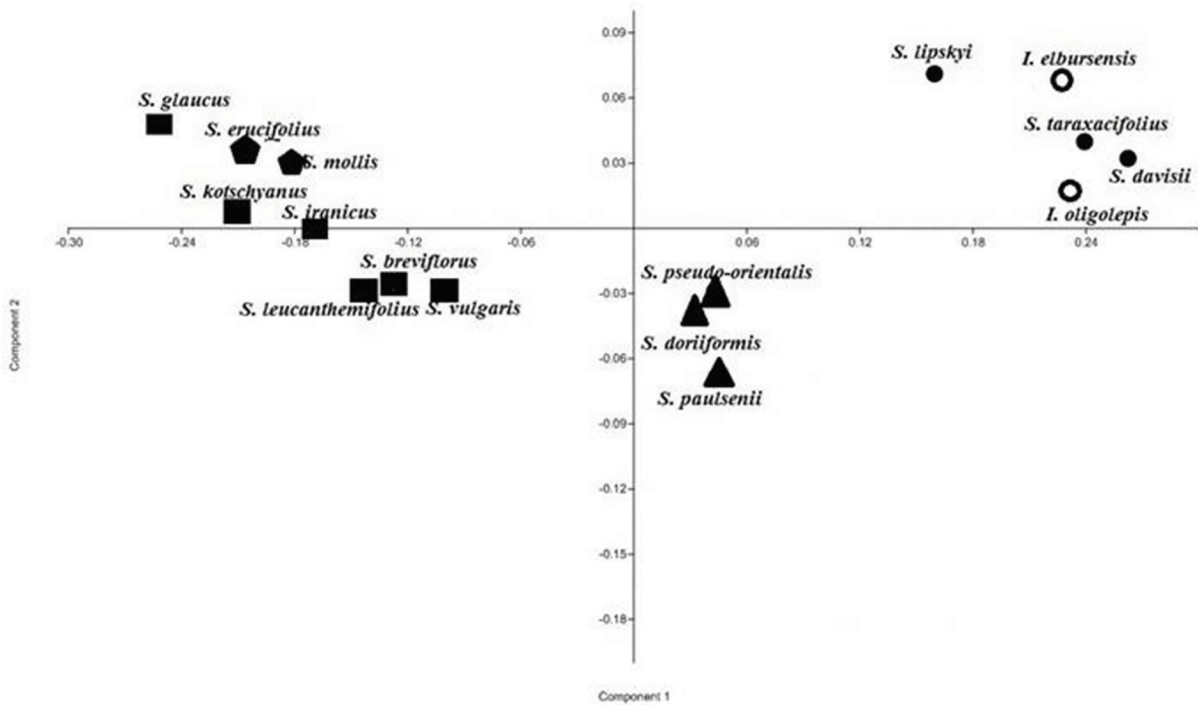


Figure 3. PCA plot of palynological characters.

Results

In the present study, the pollen grains of 14 species from 4 sections belong to the genus *Senecio* and 2 species belong to the genus *Iranecio* were investigated and SEM micrographs of all species were taken (Figs. 1, 2).

Pollen grains are isopolar and radiosymmetric, prolate-spheroidal. Their apertures are tricolporate. Polar diameters of the pollen grains ranged from 19.95 μm (*S. leucanthemifolius* sect. *Senecio*) to 36.82 μm (*S. davisii* sect. *Quadridentati*) and the equatorial diameters ranged from 1.06 μm (*S. leucanthemifolius* sect. *Senecio*) to 33.12 μm (*S. davisii* sect. *Quadridentati*) (Table 2).

According to the 16 analyzed species, the P/E ratio varied from 1.06 (*S. mollis* sect. *Jacobaea*) to 1.14 (*S. lipskyi* sect. *Quadridentati*). Spine length varied from 2.14 (*S. breviflorus*) to 3.72 μm (*S. vulgaris*). The largest number of spines was found in the species of sect. *Senecio*, (8) while species of the section *Quadridentati* and the genus *Iranecio* had the lowest numbers of spine (4). The widest distances between spines were determined in *S. davisii* sect. *Quadridentati* and *I. elbursensis* (2.45 μm) and the shortest in *S. kotschyanus* sect. *Senecio* (0.85 μm).

PCA analysis revealed that the first three components comprised about 88% of the total morphological variability. Palynological characters like spine number, perforation number and length of perforated part/spine length ratio showed the highest positive correlation (>0.80) with the first PCA component, while interspine distance and interperforation distance showed the highest positive correlation (>0.50) with the second PCA component. These characters may be use in the taxonomy of the genus and the delimitation of *Senecio* species.

The PCA plot (Fig. 3) separated the studied species into three groups. The species of the section *Quadridentati* were placed close to the species of the genus *Iranecio* (showing palynological similarities) and formed first group. Also, the species of the section *Senecio* and *Jacobaea* were grouped together (second group) and the species of the section *Crociseris* were placed close to each other and formed third group.

Discussion

Species delimitation in the genus *Senecio* is considered to be a taxonomic and phylogenetic importance that can be

achieved through molecular studies (Pelser et al. 2007). In our study, palynological characters could delimit the studied *Senecio* species.

In this study, the results of PCA plot based on palynological characters showed separation of the species of the section *Quadridentati* from the other species of *Senecio*. The species of the section *Quadridentati* were placed close to the species of the genus *Iranecio*. Jeffrey (1992) based on anatomy characters transferred the species of the sect. *Quadridentati* to the genus *Iranecio*. Therefore, the present study supports this transfer and shows close affinity between the species of the section *Quadridentati* and the species of the genus *Iranecio* based on palynological characters.

Molecular studies using nuclear and plastid DNA have been used to resolve phylogenetic relationships within the genus *Senecio* (Greuter 2008; Nordenstam et al. 2009; Hamzaoglu et al. 2011). In some of these studies, molecular results have conflicted with morphological classification. For example, the section *Jacobaea* has been considered to be a distinct genus (Pelser et al. 2006) accompanied by a morphological overlap shared with several species of *Senecio*. In the present study, the species of the section *Senecio* and the section *Jacobaea* were grouped together showing palynological overlap. The species of the section *Crociseris* were placed close to each other. The palynological characters used could also delimit the species of the section *Crociseris*.

Species delimitation is the first step toward understanding the evolution of plants and mechanisms of their divergence. However, it is a very difficult task in plant species with recent speciation events and the complex species that faced hybridization and reticulate evolution in their history (Medrano et al. 2014). In our study, palynological characters could delimit the studied *Senecio* and *Iranecio* species. Also, palynological data could approve the transfer of the section *Quadridentati* to the genus *Iranecio*. In the present study, pollen characters (perforated part/spine length, spine number and spine length) proved to be useful characters for classification. Therefore morphological, anatomical, palynological and molecular studies could help resolve problems related to the taxonomy of *Senecio*.

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