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Pollen morphology in *Cytisus* (Papilionoideae, Leguminosae) from Morocco and the Iberian Peninsula

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Although it is generally accepted that the tribe Genisteae has rather homogeneous pollen, we have found considerable variation in pollen size and morphology in *Cytisus* and related genera (*Argyrocytistus* and *Chamaecytistus*), which match taxonomic groups defined on morphological grounds. The results of Principal Component Analysis of pollen characteristics show the following: *Cytisus* Sect. *Alburnoides* is well-delimited, with the smallest pollen grains and the simplest pattern in the tectum, fossulate-perforate to perforate; No separation of *C. villosus* (Sect. *Cytisus*) from Sect. *Alburnoides* is observed; *Cytisus* Sect. *Spartopsis*, with the largest pollen grains and reticulate to reticulate-fossulate ornamentation, forms an isolated group; *C. fontanesii* (Sect. *Heterocyttisus*) stands apart from other *Cytisus* species by its homogeneous ornamentation and the perforate instead of psilate-punctate margo. Thus, the pollen data supports its transfer to the separated genus *Chronanthos*; Pollen ornamentation and morphology also support the separation of *Argyrocyttisus battandieri* and *Chamaecytistus mollis* from *Cytisus*.

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Cytisus Desf. is distributed in Europe, northern Africa and the Canary Islands, extending also into Asia. Within the tribe Genisteae, *Cytisus* is the central genus of what has been termed the *Cytisus*-group (Bisby 1981). However, delimitation of *Cytisus* is still controversial, with taxa, which have been alternatively merged into the genus or split into several close genera (e.g. *Chronanthos*, *Argyrocyttisus*, *Chamaecytistus*). Different proposals regarding the status of these genera have been made by Frodin & Heywood (1968), Polhill (1976), Cristofolini (1997) and Talavera (1999), among others. The infrageneric and generic limits used in this study are shown in the list of Specimens Investigated. Pollen data on *Cytisus* are scarce and generally included as parts of broader studies for the whole tribe Genisteae (Prados et al. 1985), or Papilionoideae (Fernández 1987), or in pollen floras, for example Saa Otero et al. (1996). We have not found a specific study on the pollen morphology of *Cytisus*. Here we have concentrated on the Section *Spartopsis*, the species of which all occur in the Iberian Peninsula and Morocco. Species of more widely distributed sections (*Cytisus*, *Heterocyttisus*, and *Alburnoides*) were also studied as well as species the inclusion of which in *Cytisus* or related genera (*Argyrocyttisus*, *Chamaecytistus*) is still controversial. Although it is generally accepted that Genisteae has rather homogeneous pollen, we have found variations in pollen size and exine surface morphology, which match taxonomic groups established on macromorphological grounds. Thus,

pollen features add new data, which provide additional support to sectional groups currently recognised within *Cytisus*. New information is also provide which either supports the inclusion of certain species into *Cytisus* and the transfer of one species into a different genus.

MATERIAL AND METHODS

Fifty pollen samples representing 21 taxa belonging to 14 species of *Cytisus* and related genera (*Argyrocyttisus*, *Chamaecytistus*) from Morocco and the Iberian Peninsula were studied (see Specimens Investigated for collection details). Herbarium voucher specimens are retained in: MAF (Herbarium Facultad de Farmacia, Madrid, Spain), MA (Herbarium Real Jardín Botánico, Madrid, Spain) and RAB (Institut Scientifique, Rabat, Morocco).

The pollen samples were acetolysed following Erdtman (1952), and subsequently divided into fractions for light microscopy (LM), and scanning and transmission electron microscopy (SEM and TEM). For LM studies a fraction was mounted in glycerine jelly onto glass slides. Polar axis (P) and equatorial diameter (E) of 30 pollen grains per sample were measured. For scanning electron microscopy (SEM) studies, one fraction was air dried from 95% ethanol onto aluminium stubs for surface exine observation, another part was concentrated by centrifugation, washed in distilled water and centrifuged again. Small drops of the concentrate were then cut at different thicknesses (2–20 µm) using a freezing microtome following Muller (1973). The sections were transferred onto aluminium stubs, and left to dry before being gold-coated (27 nm). For TEM studies, acetolysed pollen grains were fixed in 1% glutaraldehyde, post fixed in 2% osmium tetroxide (OsO₄) and embedded in epoxy-resin. Sections (50 nm) were cut using an

ultramicrotome with a diamond knife and stained with 5% uranyl acetate.

Pollen terminology follows Punt et al. (1994).

As an indicator of flower size, fresh or rehydrated flowers from herbarium specimens were dissected and the length of the standard petal (claw excluded) was measured. Principal Component Analysis was carried out using the corresponding SAS System (1989–1995) procedures.

RESULTS AND DISCUSSION

Description of pollen grains

Pollen grains of *Cytisus* are radially symmetrical, isopolar, oblate spheroidal to prolate (P/E range: 0.94–1.43; Table I), and small to medium-sized (mean P range: 16.87–32.4 µm; Table I). The smallest grains are found in *C. multiflorus* (mean P = 16.8 µm; sample MU9528) and the largest in *C. arboreus* subsp. *catalaunicus* (P = 32.4 µm; sample AC27). The pollen grains are elliptic to circular in equatorial view (Figs. 1–4), subcircular, subtriangular to 3-lobate in polar view (Figs. 6–9), and 3-zonocolporate with very long ectoapertures (Figs. 11–13) except in *C. fontanesii*, which has medium length ectoapertures (Fig. 14), and diffuse endoapertures (Figs. 6–9, 11–12). *Argyrocytistus battandieri* has spheroidal pollen grains (P/E range: 0.93–1.05), medium size (mean P: 24.7–29.9 µm), circular in both equatorial (Fig. 5) and polar view, and 3-zonocolporate with very long ectoapertures and diffuse endoapertures. *Chamaecytistus mollis* has oblate spheroidal pollen grains (P/E: 0.91), small size (mean P: 24.6 µm), subcircular to subrhomboidal in equatorial view, triangular in polar view (Fig. 10), and 3-zonocolporate with long ectoapertures and diffuse endoapertures (Fig. 15).

In *Cytisus* the ornamentation of the tectum at the mesocolpium (Table I) ranges from reticulate (Fig. 16), with (Fig. 19) or without (Fig. 20) inclusions in the lumina, reticulate-fossulate (Fig. 21), fossulate-perforate (Fig. 22) to perforate (Fig. 23). Towards, and at, the poles, the ornamentation is finer than at the equator. All the species have a perforate tectum at the apocolpium (Figs. 13, 17), with the exception of *C. fontanesii*, which has an homogeneous fossulate-perforate ornamentation, with very thick and angular muri (Figs. 14, 18, 25). The colpi have a wide psilate-punctate margo (Fig. 26), except in *C. fontanesii* (Fig. 27) where the margo is densely perforate. The aperture membrane is rugulate in all species. *Argyrocytistus battandieri* (Fig. 24) and *Chamaecytistus mollis* (Fig. 15) have a perforate tectum.

The exine ultrastructure in *Cytisus* pollen grains (Figs. 28–39) comprises an endexine which is thin and continuous in the mesocolpium (Figs. 28–32), and thickens in the apertural region along the colpi (Figs. 28–30), often rupturing in the diffuse endoaperture zone after the acetolysis treatment (Fig. 33, arrow); a foot layer, that is thick in the mesocolpium but almost absent in the apertural region (Figs. 28–30, 35); a well-developed infratectum

(Figs. 31–32), with columellae often composed by granules arranged in radially oriented rows; and a thick and discontinuous tectum. The tectum varies in thickness; it is generally wider in pollen grains with reticulate ornamentation (Figs. 36–37) and narrower in perforate pollen grains (Fig. 38). *Argyrocytistus* and *Chamaecytistus* have a wall structure, which is similar to that of *Cytisus*. However, *Argyrocytistus battandieri* has pollen with a thin tectum and an infratectum composed of long columellae (Fig. 40), while in the pollen of *Chamaecytistus mollis* the long columellae are composed of piled granules (Fig. 41).

General trends in pollen morphology and correlation with infrageneric and generic boundaries in the *Cytisus*-group

Flower size has been used as one of the criteria to establish sectional limits in *Cytisus*. Mean flower size, represented by standard petal length (claw excluded), is shown in Table I. Mean values for groups (Sections of *Cytisus* and related genera) are shown in Fig. 42. As shown in the diagram, the extremes of flower length variation are found in *Cytisus* Sect. *Alburnoides* and section *Spartopsis*. The other groups (*Cytisus* Sect. *Cytisus* and Sect. *Heterocyttis*, *Argyrocytistus battandieri*, and *Chamaecytistus mollis*) have intermediate values.

The Principal Components Analysis (PCA), carried out with flower size (represented by standard petal length = ST) and pollen size (P, E) and ornamentation (Orn) used as variables, group the samples into three well-delimited sets (Fig. 43). Similar results are obtained when only pollen characteristics (P, E, and Orn; Fig. 44) are used as variables. In both analyses the first component accounts for most of the variation (67 and 66%, respectively), and the eigenvectors of the variables have similar weights (Tables II and III). Group 1 (Figs. 43–44) includes *C. villosus* (Sect. *Cytisus*) and all the taxa of Sect. *Alburnoides*. Section *Alburnoides* has the smallest flowers (standard length < 11.5 mm), the smallest pollen grains (P < 23.5 µm; E < 20 µm), and the simplest pattern in the tectum, varying from perforate to fossulate-perforate, with the exception of one sample of *C. oromediterraneus* (OR9509), which has a reticulate-fossulate exine. *C. villosus* (Sect. *Cytisus*) is similar to species of Sect. *Alburnoides* in pollen and flower size, and ornamentation and does not separate from section *Alburnoides* in the PCA.

Group 2 (Figs. 43–44) is well delimited and includes all the taxa of Sect. *Spartopsis*. This section has the largest flowers (standard length > 12 mm), the largest pollen grains (P > 24 µm, E > 20 µm), and the most complex pattern in the tectum (ornamentation reticulate to reticulate-fossulate).

Group 3 (Figs. 43–44) includes *Argyrocytistus battandieri*, *Chamaecytistus mollis* and *Cytisus fontanesii* (Sect. *Heterocyttis*). *A. battandieri* and *Chamaecytistus mollis* have flower and pollen size similar to Sect. *Spartopsis*, while the ornamentation is equivalent to that of Sect. *Alburnoides*.

Table I. Summary of data on pollen morphology and standard petal length.

P, E in μm .

P – polar axis; E – equatorial axis; ST – standard petal length; std – standard deviation.

Sample	P $\pm$ std	P range	E $\pm$ std	E range	P/E	Ornamentation	ST $\pm$ std (mm)
<i>Cytisus</i> Sect. <i>Spartopsis</i>							
<i>Cytisus grandiflorus</i>							
GG9599	23.9 $\pm$ 0.99	22.6–26.5	23.2 $\pm$ 1.02	21.8–27.3	1.03	reticulate	19.70 $\pm$ 1.25
GB43	28.5 $\pm$ 1.54	25.0–31.5	25.1 $\pm$ 1.12	22.9–27.2	1.14	reticulate	21.88 $\pm$ 0.98
GB13	28.4 $\pm$ 2.32	22.9–32.2	26.7 $\pm$ 1.65	21.5–30.0	1.07	–	–
GB18	27.3 $\pm$ 1.18	25.0–30.0	25.1 $\pm$ 0.91	23.6–27.2	1.09	reticulate	20.96 $\pm$ 2.19
GH3	25.6 $\pm$ 1.82	22.2–29.3	25.1 $\pm$ 1.52	22.2–27.9	1.02	reticulate	21.34 $\pm$ 1.02
<i>Cytisus scoparius</i>							
SS9302	30.3 $\pm$ 1.11	28.1–32.0	23.8 $\pm$ 1.87	21.1–30.4	1.28	reticulate	19.75 $\pm$ 0.63
SS9515	26.3 $\pm$ 1.01	25.0–28.1	23.7 $\pm$ 1.54	17.2–26.5	1.11	reticulate	–
SS9537	32.4 $\pm$ 1.26	29.6–35.1	22.8 $\pm$ 1.05	21.1–25.7	1.43	reticulate–fossulate	17.60 $\pm$ 0.84
SR9547	30.3 $\pm$ 1.74	24.2–32.8	22.3 $\pm$ 1.05	21.1–25.0	1.36	reticulate	17.70 $\pm$ 0.88
<i>Cytisus maurus</i>							
MA2	28.8 $\pm$ 1.88	25.7–32.9	28.5 $\pm$ 1.93	20.5–30.7	1.02	reticulate	18.46 $\pm$ 0.55
<i>Cytisus striatus</i>							
SE9529	22.6 $\pm$ 0.87	20.3–24.2	23.1 $\pm$ 1.01	21.1–25.0	0.98	reticulate-fossulate	21.38 $\pm$ 0.83
SE9525	27.1 $\pm$ 0.76	25.7–28.9	23.3 $\pm$ 0.59	21.8–24.2	1.16	reticulate-fossulate	19.46 $\pm$ 0.40
<i>Cytisus megalanthus</i>							
ME15	27.5 $\pm$ 1.50	22.9–30.0	28.3 $\pm$ 0.92	25.7–30.0	0.97	reticulate	18.78 $\pm$ 0.74
ME20	31.5 $\pm$ 2.08	26.5–34.3	28.6 $\pm$ 1.43	25.0–30.7	1.10	reticulate	–
ME19	27.0 $\pm$ 2.02	22.9–30.7	25.8 $\pm$ 1.42	23.6–27.9	1.05	reticulate	21.15 $\pm$ 0.55
<i>Cytisus arboreus</i>							
AA16	31.3 $\pm$ 1.42	28.9–35.1	22.3 $\pm$ 0.93	21.1–24.2	1.40	reticulate	11.50 $\pm$ 0.50
AB4	24.8 $\pm$ 1.40	22.2–27.9	22.0 $\pm$ 1.30	18.6–24.3	1.13	reticulate	15.02 $\pm$ 0.84
AB25	25.2 $\pm$ 1.35	22.2–27.9	23.4 $\pm$ 0.99	21.5–25.0	1.08	reticulate	13.12 $\pm$ 1.00
AB41	27.2 $\pm$ 1.08	25.7–29.3	23.7 $\pm$ 0.87	21.5–25.0	1.15	–	13.08 $\pm$ 0.29
AB17	25.9 $\pm$ 1.77	22.9–28.6	22.5 $\pm$ 0.94	20.7–24.3	1.15	reticulate	10.88 $\pm$ 0.23
AB23	25.7 $\pm$ 1.07	23.6–27.9	22.5 $\pm$ 0.79	20.7–24.3	1.14	reticulate	–
AB42	26.9 $\pm$ 1.13	24.2–28.9	19.6 $\pm$ 0.77	17.9–21.1	1.37	reticulate	14.33 $\pm$ 0.58
AB22	26.0 $\pm$ 0.90	24.2–28.1	21.0 $\pm$ 0.90	19.5–22.6	1.24	reticulate-fossulate	14.60 $\pm$ 2.19
AC26	27.2 $\pm$ 0.84	25.7–28.9	20.5 $\pm$ 0.76	18.7–22.6	1.33	reticulate	–
AC27	32.4 $\pm$ 1.08	30.4–35.1	23.0 $\pm$ 0.84	21.1–24.2	1.41	reticulate	12.50 $\pm$ 0.39
AT28	26.3 $\pm$ 0.89	25.0–28.1	20.6 $\pm$ 0.60	19.5–21.8	1.28	reticulate	12.00 $\pm$ 0.52
<i>Cytisus</i> Sect. <i>Alburnoides</i>							
<i>Cytisus multiflorus</i>							
MU9531	20.9 $\pm$ 0.73	19.5–21.8	17.8 $\pm$ 0.65	16.4–19.5	1.17	perforate	9.88 $\pm$ 0.38
MU9528	16.8 $\pm$ 0.86	15.6–18.7	17.9 $\pm$ 0.82	17.2–20.3	0.94	perforate	10.54 $\pm$ 0.33
MU9519	19.4 $\pm$ 0.51	18.7–20.3	17.4 $\pm$ 0.51	16.4–18.7	1.11	fossulate-perforate	9.54 $\pm$ 0.14
MU9514	19.4 $\pm$ 0.65	17.9–20.3	17.4 $\pm$ 0.52	16.4–18.7	1.11	fossulate-perforate	10.50 $\pm$ 1.04
<i>Cytisus oromediterraneus</i>							
OR29	21.5 $\pm$ 0.91	19.5–23.4	19.8 $\pm$ 1.68	17.2–22.6	1.09	perforate	8.33 $\pm$ 0.60
OR9603	20.5 $\pm$ 0.68	19.5–21.8	20.1 $\pm$ 0.62	18.7–21.1	1.02	perforate	10.79 $\pm$ 0.72
OR9509	18.5 $\pm$ 0.68	16.4–19.5	19.1 $\pm$ 0.93	17.2–21.1	0.97	reticulate-fossulate	10.50 $\pm$ 0.30
OR9532	23.1 $\pm$ 1.30	21.1–25.7	16.8 $\pm$ 1.02	14.8–18.7	1.38	fossulate-perforate	10.79 $\pm$ 0.54
OR9517	21.2 $\pm$ 0.74	19.5–22.6	19.3 $\pm$ 0.54	17.9–20.3	1.10	perforate	11.50 $\pm$ 0.43
OR9544	21.9 $\pm$ 1.45	20.3–25.0	17.0 $\pm$ 1.11	13.3–18.7	1.30	perforate	9.25 $\pm$ 0.69
<i>Cytisus x praecox</i>							
PR9530	21.6 $\pm$ 0.89	20.3–23.4	17.6 $\pm$ 0.76	16.4–18.7	1.23	fossulate-perforate	11.20 $\pm$ 0.45
PR9518	23.0 $\pm$ 0.95	21.9–25.0	17.1 $\pm$ 1.01	15.6–19.5	1.35	fossulate-perforate	11.33 $\pm$ 0.44
<i>Cytisus valdesii</i>							
VA23	22.5 $\pm$ 0.92	20.7–24.3	21.5 $\pm$ 0.97	20.0–22.9	1.05	perforate	10.83 $\pm$ 0.68
VA30	23.5 $\pm$ 1.37	20.7–26.5	22.1 $\pm$ 1.29	20.0–25.7	1.06	perforate	11.31 $\pm$ 0.78
<i>Cytisus</i> Sect. <i>Cytisus</i>							
<i>Cytisus villosus</i>							
VI31	21.9 $\pm$ 1.16	20.0–24.3	19.3 $\pm$ 1.45	16.4–21.5	1.14	fossulate-perforate	10.25 $\pm$ 0.42
VI32	22.9 $\pm$ 0.78	21.5–24.3	21.0 $\pm$ 0.71	19.3–22.2	1.10	perforate	11.46 $\pm$ 0.54
<i>Cytisus</i> Sect. <i>Heterocytisus</i>							
<i>Cytisus fontanesii</i>							
FF34	26.5 $\pm$ 1.43	24.30–30.00	27.7 $\pm$ 1.62	23.60–30.70	0.96	fossulate-perforate	12.06 $\pm$ 0.55
FF33	26.0 $\pm$ 0.99	24.18–28.08	26.7 $\pm$ 0.84	24.96–28.08	0.97	fossulate-perforate	13.00
FP35	25.2 $\pm$ 1.30	22.90–28.60	26.3 $\pm$ 1.30	23.60–28.60	0.96	fossulate-perforate	13.89 $\pm$ 0.43
FP36	28.6 $\pm$ 1.54	25.70–33.60	28.9 $\pm$ 1.70	22.20–30.70	0.99	fossulate-perforate	–

Table I. Continued

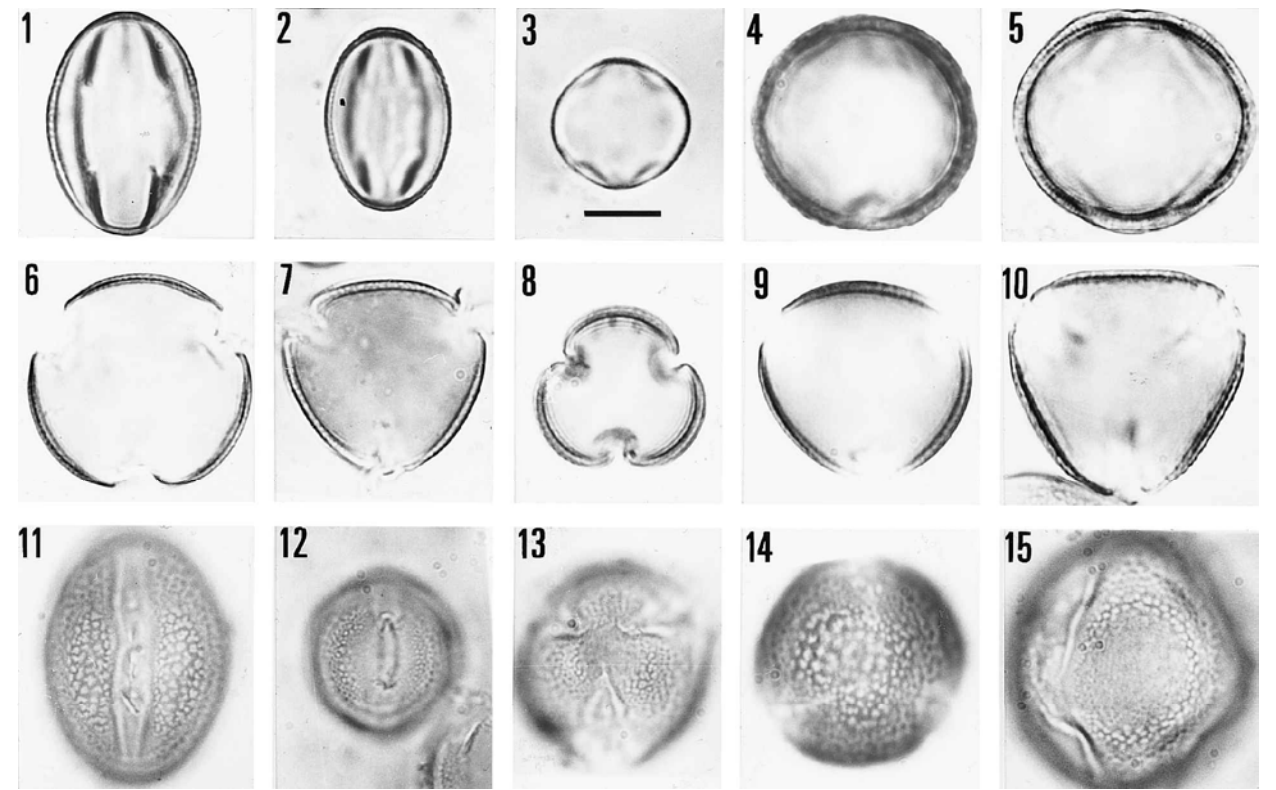
Sample	P ± std	P range	E ± std	E range	P/E	Ornamentation	ST ± std (mm)
<i>Chamaecytisus mollis</i>							
MO37	24.6 ± 1.65	20.00–27.90	27.0 ± 1.70	21.50–30.00	0.91	perforate	12.10 ± 0.70
<i>Argyrocyttis battandieri</i>							
BA40	25.9 ± 1.55	22.90–29.30	27.7 ± 0.96	25.70–30.00	0.93	perforate	13.02 ± 0.57
BA38	24.7 ± 1.74	20.70–29.30	26.5 ± 1.72	22.90–29.30	0.94	perforate	13.94 ± 0.39
BA39	29.9 ± 2.07	26.50–34.30	28.4 ± 1.81	24.30–32.20	1.05	perforate	–

Both taxa have been included in different sections of *Cytisus*: *A. battandieri* Maire in Sect. *Teline* (Maire 1987), and *Chamaecytisus mollis* (Cav.) Pau in Sect. *Tubocytisus* (Cristofolini 1991). Similarly, *Cytisus fontanesii* has flower and pollen size similar to that of Sect. *Spartopsis*, while its ornamentation (fossulate-perforate) resembles that of Sect. *Alburnoides*, although the tectum between the fossulae is prominent. Moreover, this taxon differs from the other taxa of *Cytisus* in several pollen features: the ornamentation is homogeneous, the apocolpium has the same pattern as the mesocolpium, and the perforate margo is inconspicuous in

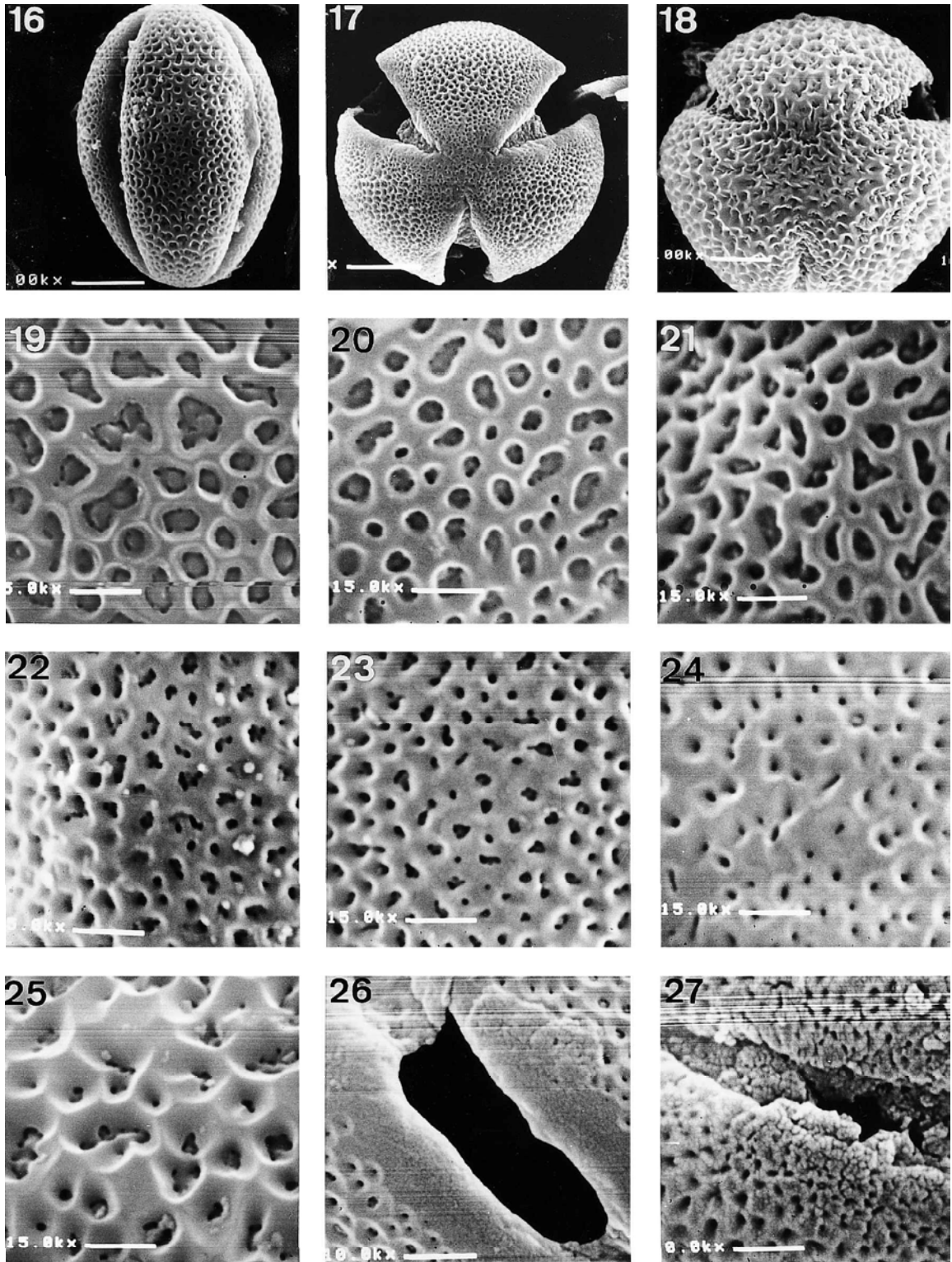
comparison with the psilate-punctate pollen margins in the other species of *Cytisus*. This species is separated from *Cytisus* by several authors and included in a different genus: *Chronanthos biflorus* (Heywood 1968).

Comparison of the pollen of *Cytisus* with other Genisteae

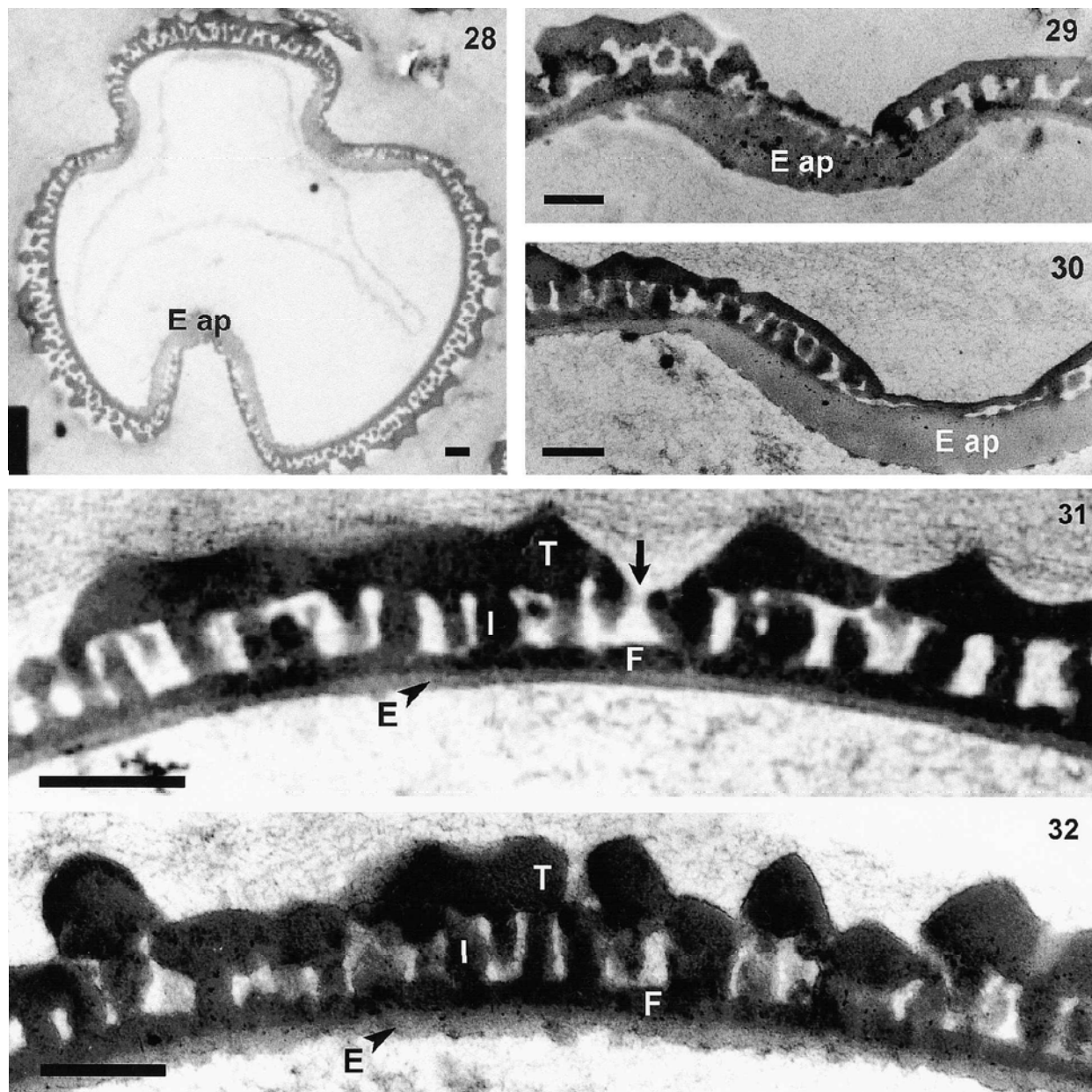
Although it has been generally accepted that Genisteae has rather homogeneous pollen (Ferguson & Skvarla 1981), several trends of variation in pollen morphology and structure have been found in different genera of Genisteae.



Figs. 1–15. LM micrographs of pollen grains. 1–5. Optical cross-section in equatorial view. (1) *Cytisus arboreus* subsp. *baeticus*, [AB4]. (2) *C. oromediterraneus*, [OR9532]. (3) *C. multiflorus*, [MU9528]. (4) *C. fontanesii* subsp. *fontanesii*, [FF33]. (5) *Argyrocyttis battandieri*, [BA40]. 6–10. Optical cross section in polar view. (6) *C. grandiflorus* subsp. *barbarus*, [GB43]. (7) *C. scoparius* subsp. *scoparius*, [SS9302]. (8) *C. arboreus* subsp. *catalaunicus*, [AC26]. (9) *C. fontanesii* subsp. *fontanesii*, [FF33]. (10) *Chamaecytisus mollis*, [MO37]. 11–12. Low focus, equatorial view. (11) *C. scoparius* subsp. *scoparius*, [SS9537]. (12) *C. multiflorus*, [MU9531]. 13–14. Low focus, polar view. (13) *C. striatus* subsp. *eriocarpus*, [SE9525]. (14) *C. fontanesii* subsp. *fontanesii*, [FF33]. (15) Low focus, equatorial view, *Chamaecytisus mollis*, [MO37]. Scale bar = 10 µm.



Figs. 16–27. SEM micrographs. (16). Equatorial view, *Cytisus megalanthus*, [ME19]. 17–18. Polar view. (17) *C. grandiflorus* subsp. *barbarus*, [GB18]. (18) *C. fontanesii* subsp. *fontanesii*, [FF33]. 19–25. Pollen surface pattern at the mesocolpium. (19) Reticulate with inclusions in the lumina, *C. arboreus* subsp. *arboreus*, [AA16]. (20) Reticulate, *C. scoparius* subsp. *scoparius*, [SS9515]. (21) Reticulate-fossulate, *C. striatus* subsp. *eriocarpus*, [SE9529]. (22) Fossulate-perforate, *C. multiflorus*, [MU9514]. (23) Perforate, some lumina are slightly fossulate, *C. valdesii*, [VA30]. (24) Perforate, *Argyrocyttis battandieri*, [BA39]. (25) Fossulate-perforate with very wide muri, *C. fontanesii* subsp. *fontanesii*, [FF33]. 26–27. Colpus margins. (26) Psilate-punctate margo, *C. villosus*, [VI32]. (27) Perforate margo, *C. fontanesii* subsp. *plumosus*, [FP35]. Scale bar in Fig. 16=6.6 μ m, Figs. 17–18=5 μ m, Figs. 19–25=1.3 μ m, Figs. 26–27=2 μ m.



Figs. 28–32. TEM micrographs. (28) Thin section of pollen grain at the subequatorial region, *Cytisus multiflorus*, [MU9528], the granular appearance of the infratectum is due to the slightly oblique section. 29–30. Sections showing the thickening of the endexine and the disappearing of the tectum at the apertural region. (29) *C. oromediterraneus*, [OR9509]. (30) *C. striatus* subsp. *eriocarpus*, [SE9529]. 31–32. Structure of the pollen wall at the mesocolpium. (31) *C. multiflorus*, [MU9528], arrow indicate a perforation. (32) *C. striatus* subsp. *eriocarpus*, [SE9529], note the diameter of the lumina, larger than in Fig. 31. E=endexine, E ap=endexine at the apertural level, F=foot layer, I=infratectum, T=tectum. Scale bar=0.5 μ m.

For example, in *Ulex* and *Stauracanthus*, the pollen size and structure type are related to ploidy level, as well as to flower length and seed size (Cubas & Pardo 1992, 1994). In *Genista*, differences in structural type are also related to different ploidy levels while changes in chromosome number associated with aneuploidy processes are not reflected in variations in pollen wall structure (Pardo et al. 1994). In the *Cytisus*-group the same trend is observed: there is very little variation in the pollen wall structure, which may be related

to the absence of different ploidy levels in the taxa of *Cytisus* studied here (Sañudo 1973, Cubas et al. in press.). However, we observe clear variations in pollen size and ornamentation that in turn can be related to differences in flower size.

CONCLUSIONS

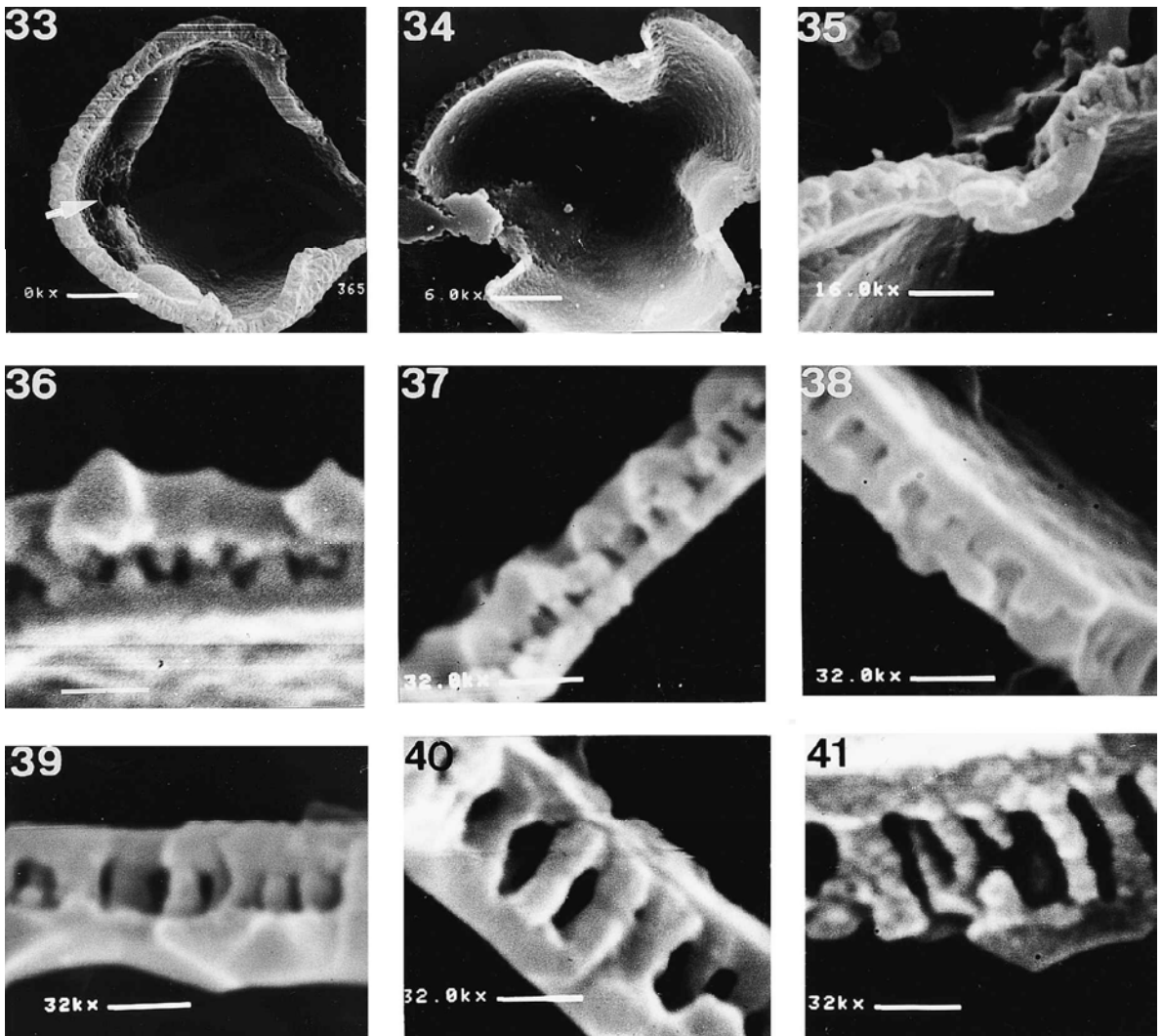
Although pollen morphology tends to be homogeneous in *Cytisus*, we have found several trends in pollen size and

ornamentation that can be related to flower morphology. Principal Component Analysis indicates that pollen characters are as good as flower size to delimit groups. Pollen characteristics correlate well with the current limits established within *Cytisus*. Pollen characteristics support the separation of Sect. *Alburnoides* from Sect. *Spartopsis*, but do not corroborate the separation of *C. villosus* (Sect. *Cytisus*) from Sect. *Alburnoides*. Pollen data also support the separation of *Argyrocytissus* and *Chamaecytissus* as independent genera. Additionally, from pollen morphological point

of view *Cytisus fontanesii* (Sect. *Heterocyttisus*) stands apart from other *Cytisus* species. Therefore, the pollen evidence supports the removal of *Cytisus fontanesii* to the separated genus *Chronanthos* (Heywood 1968).

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Figs. 33–41. SEM micrographs. (33) Meridional section showing the diffuse endoaperture zone (arrow) and the endexine thickened along the colpi, *C. fontanesii* subsp. *plumosus*, [FP35]. (34) Equatorial section, *C. oromediterraneus*, [OR9532]. (35) Section of the apertural fold at the subequatorial region with thick endexine, *C. oromediterraneus*, [OR9517]. 36–41. Exine structure. (36) *C. grandiflorus* subsp. *haplophyllus*, [GH3], note the thick tectum and the apiculate muri. (37) *C. grandiflorus* subsp. *barbarus*, [GB18], the inclusions of the lumina are clearly visible. (38) *C. multiflorus*, [MU9519], even tectum showing the perforations. (39) *C. fontanesii* subsp. *fontanesii*, [FF33], thick tectum. (40) *Argyrocyttisus battandieri*, [BA39], note the long columellae. (41) *Chamaecytissus mollis*, [MO37], note the columellae composed of piled granules. Scale bar in Fig. 33=5 μm , Fig. 34=3.3 μm , Fig. 35=1.25 μm , Figs. 36–41=0.6 μm .

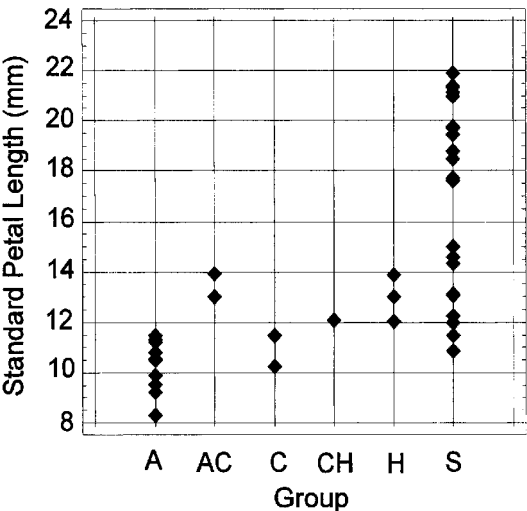


Fig. 42. Scatterplot of sample mean standard petal length (mm) by sections of *Cytisus* (A – Sect. *Alburnoides*, C – Sect. *Cytisus*, H – Sect. *Heterocytisus*, S – Sect. *Spartopsis*), *Argyrocytisus* (AC), and *Chamaecytisus* (CH).

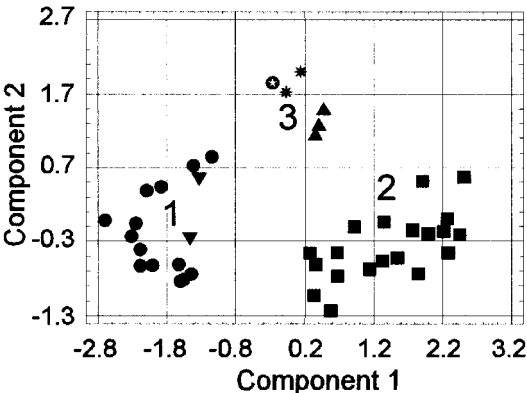


Fig. 43. Two-dimensional scatterplot of Principal Component Analysis using pollen morphology (P, E, Orn) and standard petal length (ST) as variables, for samples of *Cytisus* (● Sect. *Alburnoides*, ▼ Sect. *Cytisus*, ▲ Sect. *Heterocytisus*, ■ Sect. *Spartopsis*), *Argyrocytisus* (*), and *Chamaecytisus* (⊕).

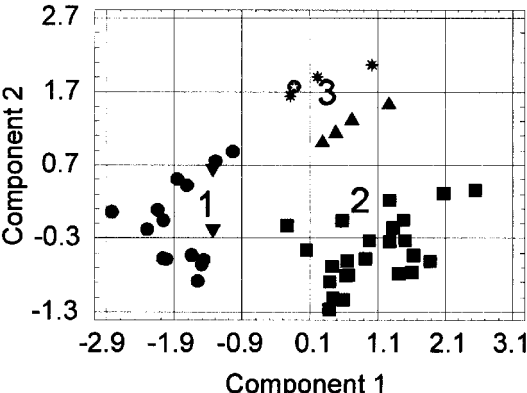


Fig. 44. Two-dimensional scatterplot of Principal Component Analysis using pollen morphology (P, E and Orn) as variables, for samples of *Cytisus* (● Sect. *Alburnoides*, ▼ Sect. *Cytisus*, ▲ Sect. *Heterocytisus*, ■ Sect. *Spartopsis*), *Argyrocytisus* (*), and *Chamaecytisus* (⊕).

Table II. Summary of the statistics for the Principal Components Analysis using pollen morphology characters (P, E, Orn) and standard petal length (ST) as variables.

Correlation Matrix				
	P	E	ORN	ST
P	1.0000	0.5954	0.6430	0.5546
E	0.5954	1.0000	0.3151	0.5857
Orn	0.6430	0.3151	1.0000	0.6559
ST	0.5546	0.5857	0.6559	1.0000

Eigenvalues of the Correlation Matrix				
Component	Eigenvalue	Difference	Proportion	Cumulative
1	2.68161	1.99403	0.670403	0.67040
2	0.68758	0.24270	0.171895	0.84230
3	0.44488	0.25896	0.111220	0.95325
4	0.18529	0.00000	0.046481	1.00000

Eigenvectors				
	Component 1	Component 2	Component 3	Component 4
P	0.523109	0.006421	-0.711591	-0.468992
E	0.459618	0.755700	0.038238	0.464981
Orn	0.523928	-0.058693	0.701079	-0.480149
ST	0.490518	-0.652252	-0.025789	0.577317

Table III. Summary of the statistics for the Principal Components Analysis using pollen morphology characters (P, E, Orn) as variables.

Correlation Matrix			
	P	E	Orn
P	1.0000	0.6394	0.5800
E	0.6394	1.0000	0.2371
Orn	0.5800	0.2371	1.0000

Eigenvalues of the Correlation Matrix				
Component	Eigenvalue	Difference	Proportion	Cumulative
1	1.98949	1.22529	0.663162	0.66316
2	0.76420	0.51788	0.254732	0.91789
3	0.24632	0.00000	0.082105	1.00000

Eigenvectors			
	Component 1	Component 2	Component 3
P	0.657321	-0.031367	-0.752957
E	0.548559	-0.665165	0.506594
Orn	0.516731	0.746037	0.420021

SPECIMENS INVESTIGATED

The numbers in square parentheses refer to Authors personal collection.

Cytisus* Desf.*Sect. *Spartopsis* Dumort.***C. grandiflorus* (Brot.) DC. subsp. *grandiflorus*

PORTUGAL: Serra da Estrela, Lagoa Comprida, 1550 m, MAF148191 [GG9599].

C. grandiflorus subsp. *barbarus* (Jahandiez & Maire) Maire

MOROCCO: Moyen Atlas, Jbel Tazekka loc. 1, 1150 m, RAB62124 [GB43];

MOROCCO: Moyen Atlas, Jbel Tazekka loc. 2, 1150 m, RAB62126 [GB13];

MOROCCO: Haut Atlas, Jbel Oukaïmeden, 2550 m, RAB62120 [GB18].

C. grandiflorus subsp. *haplophyllus* (Maire & Sennen) Maire

MOROCCO: littoral de la Méditerranée, Jbel Gourougou, 850 m, RAB62123 [GH3].

C. scoparius (L.) Link subsp. *scoparius*

SPAIN: Pontevedra, Playa de Bascuas, Xanxenxo, MAF157205 [SS9302];

SPAIN: Avila, Puerto de Casillas a Casillas, MAF147891 [SS9515];

SPAIN: Avila, Arrabal de Pesquera, Piedrahita, 1250 m, MAF147912 [SS9537].

C. scoparius subsp. *reverchonii* (Degen & Hervier) Rivas Goday & Rivas Mart.

SPAIN: Albacete, Puerto de las Crucetillas, 1530 m, MAF148714 [SR9547].

C. maurus Humbert & Maire

MOROCCO: Moyen Atlas, Jbel Tazekka, 1150 m, RAB62130 [A2].

C. striatus (Hill) Rothm. subsp. *eriocarpus* (Boiss. & Reuter) Rivas Mart.

SPAIN: Avila, Puerto del Pico a Cuevas del Valle, MAF147904 [SE9529];

SPAIN: Avila, Puerto del Pico, base de la Rubia, 1420 m, MAF147900 [SE9525].

C. megalanthus (Pau & Font Quer) Font Quer

MOROCCO: Rif, 5 Km avant Issaguène en allant vers Bab Berred, 1450 m, RAB62118 [ME15];

MOROCCO: Rif, Solanas de Bab Taziat (Bni Jaled), RAB6214 [ME20];

MOROCCO: Rif, 12 km avant Bad Berred, en direction de Bab Taza, 1300 m, RAB62117 [ME19].

C. arboreus (Desf.) DC. subsp. *arboreus*

MOROCCO: monts du Maroc oriental, Bni-Snassène, Ras Foughal, 1000–1500 m, RAB62164 [AA16].

C. arboreus subsp. *baeticus* (Webb) Maire

MOROCCO: littoral de la Méditerranée, Jbel Gourougou, 850 m, RAB62140 [AB4];

MOROCCO: Maroc atlantique moyen, forêt de Benslimane, RAB62134 [AB25];

MOROCCO: Moyen Atlas, Ain Vittel, 1500 m, RAB62143 [AB41];

MOROCCO: Maroc atlantique moyen, forêt de Mohammedia, RAB62135 [AB17];

MOROCCO: Près d'Ouazzane, RAB62139 [AB23];

SPAIN: Málaga, Ronda, Montajaque, 650 m, MA336256 [AB42];

PORTUGAL: Santiago do Cacém, cerca de Alentejo, próximo de Pereiros, MA412720 [AB22].

C. arboreus subsp. *catalaunicus* (Webb) Maire

SPAIN: Barcelona, Massif du Tibidabo, près Vista Rica, MA159783 [AC26];

MOROCCO: Moyen Atlas, Ksiba, 1000 m, RAB62165 [AC27].

C. arboreus subsp. *transiens* (Webb) Maire

MOROCCO: Zaine, Ezhiligga, parcelle des Eaux et Forêts, RAB1944 [AT28].

Sect. *Alburnoides* DC.*C. multiflorus* (L'Hér.) Sweet

SPAIN: Avila, Puerto del Pico, 1420 m, MAF147906 [MU9531];

SPAIN: Avila, Puerto del Pico a Cuevas del Valle, MAF147903 [MU9528];

SPAIN: Avila, Mijares a Puerto de Mijares, 1510 m, MAF147895 [MU9519];

SPAIN: Avila, Puerto de Casillas a Casillas, 1400 m, MAF147890 [MU9514].

C. oromediterraneus Rivas Mart. et al.

SPAIN: Salamanca, El Tejado, 990 m, MAF157204 [OR29];

SPAIN: Madrid, Puerto de Guadarrama, MAF153705 [OR9603];

SPAIN: Avila, Casillas, 900 m, MAF147887 [OR9509];

SPAIN: Avila, Puerto del Pico, 1420 m, MAF147907 [OR9532];

SPAIN: Avila, Mijares a Puerto de Mijares, 1510 m, MAF147893 [OR9517];

SPAIN: Madrid, Puerto de la Morcuera, 1700 m, MAF148743 [OR9544].

C. x praecox Bean

SPAIN: Avila, Puerto del Pico, 1420 m, MAF147905 [PR9530];

SPAIN: Avila, Mijares a Puerto de Mijares, 1510 m, MAF147894 [PR9518].

C. valdesii Talavera & Gibbs

MOROCCO: Haut Atlas, Jbel Oukaïmeden, 2650 m, RAB62147 [VA23];

MOROCCO: Moyen Atlas, Tizi-n-Tretten, 2100 m, RAB62149 [VA30].

Sect. *Cytisus**C. villosus* Pourret

MOROCCO: Maroc atlantique nord, Région de Khemisset, RAB46048 [VI31];

MOROCCO: Moyen Atlas, Massif Zerhoun, versant N, route allant du col de Zerhoun à Moulay Driss, RAB40784 [VI32].

Sect. *Heterocytisus* Nyman ex Briq.*C. fontanesii* Ball subsp. *fontanesii*

MOROCCO: Plateaux du Maroc oriental, 4 Km avant Zaida en allant vers Midelt, 1450 m, RAB62145 [FF34];

SPAIN: Málaga, Antequera-Abdalajis, MAF 74508 [FF33].

C. fontanesii subsp. *plumosus* (Boiss.) Nyman

MOROCCO: Moyen Atlas, 10 Km après Imouzzer en direction d'Ifrane, RAB62146 [FP35];

MOROCCO: Rif, Chaouène, Jbel Quala, RAB912 [FP36].

Chamaecytisus* LinkC. mollis* (Cav.) Greuter & Burdet

MOROCCO: Maroc atlantique moyen, entre Bir Jdid et Souk el Tnine, RAB62154 [MO37].

Argyrocytisus* (Maire) C. RaynaudA. battandieri* (Maire) C. Raynaud

MOROCCO: Moyen Atlas, sur la route Azrou vers Timahdite, 1800 m, RAB62152 [BA40];

MOROCCO: Rif, maison forestière de Khandak Anassar, RAB62151 [BA38];

MOROCCO: Rif, Jbel Tizirène, 1800 m, RAB62150 [BA39].

REFERENCES

- Bisby, F. A. 1981. Genisteae (Adans.) Benth. – In: *Advances in Legume Systematics*, 1 (ed. R. M. Polhill & P. H. Raven), pp. 409–425. – Royal Botanic Gardens, Kew.
- Cristofolini, G. 1991. Taxonomic revision of *Cytisus* Desf. Sect. *Tubocytisus* DC. (Fabaceae). – *Webbia* 45: 187–219.
- Cristofolini, G. 1997. The biodiversity of the Leguminosae-Genisteae and its genesis. – *Lagascalia* 19: 121–128.
- Cubas, P. & Pardo, C. 1992. Pollen wall stratification in *Ulex* (Genisteae, Papilionoideae: Leguminosae) in the Iberian Peninsula. – *Grana* 31: 177–185.
- Cubas, P. & Pardo, C. 1994. Morfología y biometría del polen del género *Ulex* L. (Genisteae, Papilionoideae). – In: *Polen y*

- esporas: contribución a su conocimiento (ed. I. de la Serna), pp. 19–33. – Universidad de La Laguna, Tenerife.
- Cubas, P., Tahiri, H. & Pardo, C. 2001. Karyological and taxonomic notes on *Cytisus* Desf. Sect. *Spartopsis* Dumort. and Sect. *Alburnoides* DC. (Genisteae, Leguminosae) from the Iberian Peninsula and Morocco. – Botanical Journal of the Linnean Society, vol 135 (in press).
- Erdtman, G. 1952. Pollen morphology and plant taxonomy, I. Angiosperms. – Almqvist & Wiksell, Stockholm.
- Ferguson, I. K. & Skvarla, J. J. 1981. The pollen morphology of the subfamily Papilionoideae (Leguminosae). – In: Advances in Legume Systematics, 2 (ed. R. M. Polhill & P. H. Raven), pp. 859–896. – Royal Botanic Gardens, Kew.
- Fernández, I. 1987. Fabaceae (Papilionaceae). – In: Atlas polínico de Andalucía Occidental (ed. B. Valdés, M. J. Díez & I. Fernández), pp. 185–200. – Inst. Dess., Sevilla.
- Frodin, D. G. & Heywood, V. H. 1968. *Cytisus* L. – In: Flora Europaea, 2 (ed. T. G. Tutin, V. H. Heywood, N. A. Burges, D. M. Moore, D. H. Valentine, S. M. Walters & D. A. Webb), pp. 86–93. – Univ. Press, Cambridge.
- Heywood, V. H. 1968. A synopsis of the European species of *Cytisus* and allied genera. – Feddes Repertorium 79: 20–23.
- Maire, R. 1987. Flore de l'Afrique du Nord, 16. – P. Lechevalier, Paris.
- Muller, J. 1973. Pollen morphology of *Barringtonia calytracalyx* K. Sch. (Lecythydeaceae). – Grana 13: 29–44.
- Pardo, C., Cubas, P. & Sánchez Testillano, P. 1994. Tendances évolutives de la structure exinique dans les genres *Ulex*, *Stauracanthus* et *Genista* (Genisteae, Papilionoideae: Leguminosae). – Acta Botanica Gallica 141: 195–205.
- Polhill, R. M. 1976. Genisteae (Adans.) Benth. and related tribes (Leguminosae). – Botanical Systematics 1: 143–368.
- Prados, A., Ubert, J. L. & Dominguez, E. 1985. Estudio palinológico de la tribu Genisteae R. Br. en Andalucía Occidental. – Anales de la Asociación de Palinólogos de Lengua Española (A.P.L.E.) 2: 35–41.
- Punt, W., Blackmore, S., Nilsson, S. & Le Thomas, A. 1994. Glossary of pollen and spore terminology. – LPP Foundation, Utrecht.
- Saa Otero, M. P., Suárez-Cervera, M. & Gracia, V. R. 1996. Atlas de polen de Galicia. 1: 155–157. – Deputación de Ourense, Ourense.
- Sañudo, A. 1973. Variabilidad cromosómica de las genisteas de la flora española en relación con su ecología. I. – Número y comportamiento de los cromosomas durante la meiosis. E. Género *Cytisus* L. – Boletín de la Real Sociedad Española de Historia Natural, Sección Biológica 7: 341–355.
- SAS System (1989–1995). SAS System for Windows, release 6.12. – SAS Institute INC., Cary NC.
- Talavera, S. 1999. *Cytisus* Desf. – In: Flora Iberica, 7.1 (ed. S. Talavera, C. Aedo, C. Romero, L. Sáez, F.-J. Salgueiro & M. Velasco), pp. 147–182. – CSIC, Madrid.