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MICROMORPHOLOGICAL STUDIES OF *LALLEMANTIA* L. (LAMIACEAE) SPECIES GROWING IN TURKEY

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Micromorphological features related to the pollen, nutlets and trichomes of *Lallemantia* species growing in Turkey were investigated mainly by scanning electron microscopy. *Lallemantia* pollen shares morphological features with subfamily Nepetoideae (tribe Mentheae, subtribe Nepetinae) pollen. However, the fine details are characteristic enough to differentiate the pollen between species. The exine is microreticulate in *L. peltata* and *L. iberica*, and reticulate-foveolate in *L. canescens*. Similarly, nutlet features are similar in general, but there are striking differences in surface details between species. Nutlets are black and oblong-triangular with V-shaped areoles. The surface is verrucate in *L. iberica* and *L. canescens*, and verrucate-rugulate in *L. peltata*. The warts are regular and separated in *L. peltata*, irregular and separated in *L. iberica*, and irregular and separated or sometimes associated in 2 to 4 groups in *L. canescens*. Two types of trichome, capitate and acicular, are present on the stems, leaves, calyx and bracts. The results suggest that although the distribution and micromorphology of trichomes has no taxonomic value, some pollen and nutlet micromorphological characters have the potential to serve as phylogenetic markers at the species level in the genus *Lallemantia*. However, pollen characteristics show no correlation with the nutlet characteristics.

Key words: Lamiaceae, *Lallemantia*, Mentheae, micromorphology, pollen, nutlet, trichomes, Nepetinae, taxonomy.

INTRODUCTION

The family Lamiaceae contains 236 genera and about 7173 species. They are almost cosmopolitan but absent from the coldest regions of high altitude or latitude. Erdtman (1945) divided the pollen of the Lamiaceae into two main groups based on aperture number and number of nuclei in shed pollen. The first group has tricolpate pollen grains and comprises the subfamily Lamioideae. The second group has hexacolpate pollen grains and comprises the subfamily Nepetoideae (Cantino and Sanders, 1986). Subfamily Nepetoideae has often strongly aromatic species with volatile terpenoids, rosmarinic acid and usually hexacolpate pollens. The genus *Lallemantia* L., comprising herbaceous annual or biennial plants, is characterized by simple leaves; a thyrsoid, spike-like or oblong, often interrupted inflorescence; ovate to rotund or sometimes linear, aristate-toothed bracteoles; and oblong, trigonous, smooth and mucilaginous nutlets (Harley et al., 2004). Subfamily Nepetoideae is also divided into the tribes Elsholtzieae, Lavanduleae, Mentheae and Ocimeae (Harley, 1992; Harley et al., 1992). Tribe Mentheae consists of three subtribes: Salviinae, Menthinae and Nepetinae. The Nepetinae differ from the two other Mentheae subtribes in the length of the posterior pair of stamens and the number of calyx nerves (Wagstaff, 1992). Nepetinae consists of 12 genera and about 350 species distributed over large parts of Eurasia and North America. The genus *Lallemantia* is included in Nepetinae (Harley et al., 2004). *Lallemantia* species can be used for a variety of purposes, including food, lighting and medicine. *Lallemantia iberica* Fisch. & C.A. Mey. is cultivated in Iran and southern parts of the former USSR as an oil-seed plant (Rivera Nunez and Obon de Gastro, 1992).

Investigations of pollen morphology in the Lamiaceae have proven essential as an aid to classification within the family (Abu-Asab and Cantino, 1992, 1993, 1994). Pollen morphology generally

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TABLE 1. Studied materials of *Lallemantia* species

Species	Locality	Collection data
L. peltata	C5 MERSİN: Aslanköy, Cocakdere, Şahinkayası, river banks, 1500 m, 07.06.2003	M.Dinç 1615[a,c,d] (KNYA)
	A4 ÇANKIRI: Eldivan Dağı, Kızılmeşe çevresi, bozkır tarla, 1500 m, 22.07.1984	Ş.Yıldırımlı 7039[b,c] (Yıldırımlı Herb.)
	C4 KARAMAN: Sarıveliler, Turanşah Dağı, Çevlik mevkii, eğimli yamaçlar, kayalık, 1850 m, 15.06.2007	S.Doğu 1084[c] (KNYA)
L. iberica	B5 AKSARAY: Fatmauşağı Köyü civarı, step, 1250 m, 27.06.1997	M.Dinç 378[a,c] (KNYA)
	C5 MERSİN: Aslanköy, Cocakdere, Ardıçlıolouk, *Juniperus excelsa* clearings, 2000-2100 m, 04.07.2003	M.Dinç 1886[b,c,d] (KNYA)
	B7 ERZİNCAN: Kemah, Munzur Dağları, Maksutuşağı Köyü aşağısı, Karasu çevresi, 1200 m, 29.05.1979	Ş.Yıldırımlı 1770[c] (Yıldırımlı Herb.)
	C4 KARAMAN: Sarıveliler, Yalman Tepe, meşe açıklığı, 1250 m, 23.05.2007	S.Doğu 905[c] (KNYA)
L. canescens	A9 KARS: Kağızman, Çengilli Köyü, Oynak Harabe Mevkii, taşlık alanlar, 2100 m, 19.08.1979	O.Güneş 1465[b,c] (Yıldırımlı Herb.)
	A9 KARS: Sarıkamış, Mescitli Köyü-orman arası, 1900 m, 11.07.1981	O.Güneş 1964[a,c] (Yıldırımlı Herb.)
	B7 ERZİNCAN: Kemah, Munzur Dağları, Uluçınar Köyü çevresi, 1500 m, 28.05.1979	Ş.Yıldırımlı 1675[c,d] (Yıldırımlı Herb.)

[a]Specimens used for pollen studies; [b] Specimens used for nutlet studies; [c]Specimens used for trichome studies by stereomicroscopy; [d]Specimens used for trichome studies by SEM

supports the segregation of some genera of Lamiaceae such as *Phlomis* L., *Marrubium* L. and *Stachys* L. (Abu-Asab and Cantino, 1994). However, its taxonomic value for infrageneric classification varies in the family Lamiaceae. Although pollen characters support sectional and even interspecific classification in some genera (Oybak-Dönmez et al., 1999; Dinç and Öztürk, 2008), their value for taxonomic application is very limited in the genus Lycopus (Moon and Hong, 2003).

Studies on nutlet in Lamiaceae have shown it to be useful to varying degrees at different levels of the taxonomic hierarchy (Nabli, 1970, 1972; Abu-Assab and Cantino, 1992; Marin et al., 1994; Navarro and El Oualidi, 2000; Moon and Hong, 2006; Dinç and Dogan, 2006; Kaya and Kutluk, 2007; Kaya and Dirmenci, 2008). In particular, the anatomy of the pericarp in connection with myxocarpy (i.e., the phenomenon of producing mucilage when the nutlets become wet) in the family Lamiaceae has also been considered a very useful taxonomic characteristic (Harley et al., 2004; Moon and Hong, 2006).

Trichomes are of great interest to descriptive and experimental botanists; data on trichomes and indumenta are routinely included in many types of studies. As simple morphological tools, trichomes are useful because of the ease with which they are examined and their almost universal occurrence, particularly among the ferns and flowering plants. Beyond their purely descriptive use, comparative data may be important for the study of evolution and relationships, and for the roles of hairs in various aspects of physiological and ecological adaptation (Payne, 1978). Many authors, including Servettaz et al. (1994), Bini Maleci et al. (1995), Navarro and El Oualidi (2000), Jurišić Grubešić et al. (2007) and Dinç and Öztürk (2008), emphasize the great value of trichomes in Lamiaceae taxonomy.

The genus *Lallemantia* is represented by five species distributed in Afghanistan, China, India, Kazakhstan, Kyrgyzstan, Pakistan, Russia, Tajikistan, Turkmenistan, Uzbekistan, SW Asia, and Europe (Cao Shu, 1994). Three of them, *L. peltata* (L.) Fisch. & C.A.Mey., *L. iberica* (M.Bieb.) Fisch. & C.A.Mey. and *L. canescens* (L.) Fisch. & C. A. Mey., grow in Turkey. This paper provides a detailed description of nutlet, pollen and trichome morphology in *Lallemantia* species growing in Turkey, mainly by scanning electron microscopy (SEM), and evaluates the systematic significance of such characteristics.

MATERIALS AND METHODS

Material used for this study was taken from wild populations as well as from KNYA and Yildirimli herbaria. A list of all taxa studied is provided (Tab. 1).

For palynological study, pollen grains were mounted directly on stubs with single-side adhesive tape and coated with gold. The grains were examined by SEM, and the best representatives were photographed in general and in detail. In each sample, 50 pollen grains were measured in order to obtain the maximum, minimum and average size values. Pollen terminology follows Faegri and Iversen (1989) and Punt et al. (1994).

TABLE 2. Statistical description of quantitative micromorphological characters of *Lallemantia* species in Turkey

Character	Species	N	Mean	SD	SE	95 % confidence for mean		Min.	Max.
						Lower limit	Upper limit		
Pollen polar axis	*L. peltata*	50	30.2	1.66	0. 37	29.42	30.98	27.4	35.00
	L. iberica	50	1.51	0.13	0.021	1.47	1.55	1.32	1.86
	L. canescens	50	1.42	0.09	0.015	1.40	1.46	1.25	1.66
Pollen equatorial axis	*L.peltata*	50	22.00	1.39	0.31	21.34	22.65	30.10	25.30
	L. iberica	50	23.30	1.08	0.24	22.79	23.80	30.10	25.30
	L. canescens	50	29.30	1.35	0.30	28.56	29.83	24.70	32.10
Pollen colpus length	*L.peltata*	50	26.30	1.30	0.26	25.63	26.76	24.10	29.30
	L. iberica	50	29.80	1.64	0.36	29.02	30.57	26.70	34.50
	L. canescens	50	36.80	1.77	0.39	35.96	37.63	33.00	41.00
Pollen colpus width	*L. peltata*	50	1.80	0.59	0.13	1.52	2.07	0.80	3.00
	L. iberica	50	1.30	0.17	0.039	1.21	1.38	0.80	1.60
	L. canescens	50	1.60	0.32	0.073	1.44	1.75	1.00	2.60
P/E ratio	*L. peltata*	50	1.40	0.079	0.0177	1.36	1.43	1.30	1.50
	L. iberica	50	1.50	0.072	0.016	1.46	1.53	1.40	1.60
	L. canescens	50	1.40	0.30	0.045	1.30	1.49	1.10	1.80
Nutlet length	*L. peltata*	50	3.50	0.12	0.028	3.44	3.55	3.30	3.75
	L. iberica	50	3.75	0.093	0.030	3.70	3.79	3.65	4.00
	L. canescens	50	4.30	0.11	0.026	4.14	4.25	4.00	4.40
Nutlet width	*L. peltata*	50	1.50	0.11	0.025	1.44	1.55	1.30	1.70
	L. iberica	50	1.75	0.069	0.015	1.71	1.78	1.60	1.90
	L. canescens	50	1.50	0.14	0.019	1.54	1.62	1.30	1.90

TABLE 3. Qualitative pollen and nutlet characteristics of *Lallemantia* species growing in Turkey

Character/Species	*L. peltata*	*L. iberica*	*L. canescens*
Ppollen shape in equatorial view	prolate-subprolate	prolate	prolate-prolate spheroidal
Pollen shape in polar view	circular	circular	circular
Pollen ornamentation	microreticulate	microreticulate	reticulate-foveolate
Pollen aperture type	6-zonocolpate	6-zonocolpate	6-zonocolpate
Nutlet shape	oblong-triangular	oblong-triangular	narrowly oblong-triangular
Nutlet color	black	black	black
Nutlet surface	verrucate-rugulate	verrucate	verrucate

Nutlets were first observed with a stereomicroscope to ensure that they were of normal size and maturity. For nutlet length and width, 50 samples of each taxon were taken and measured. Mature nutlets were also mounted directly on aluminum stubs and coated with gold, after which they were observed and photographed as in the palynological study.

Statistical descriptions of the quantitative micromorphological characters of *Lallemantia* species growing in Turkey are given in Table 2. The scores were analyzed by one-way ANOVA (Tab. 4), and homogeneous subsets by the Tukey test (Tab. 5).

The specimens of each species were first examined with a stereomicroscope. The distribution and types of trichomes were determined. The bracts of the specimens of each species were also mounted directly on aluminum stubs and gold-coated, after which representative trichomes of each taxon were photographed. Trichomes were determined according to Metcalfe and Chalk (1972), Payne (1978) and Bini Maleci et al. (1995).

RESULTS

Representative pollen grains of each species are illustrated (Fig. 1) and size and shape measurements are provided (Tabs. 2, 3). The pollen grains of all species examined in the genus *Lallemantia* in Turkey are single, isopolar and hexacolpate. The dimension

TABLE 4. ANOVA of quantitative micromorphological characters of *Lallemantia* species in Turkey (results significant at $p \leq 0.05$)

Character	Scope	Sum of squares	df	Mean square	F	p
Pollen polar axis	Between groups	981.733	2	490.867	118.637	0.000
	Within groups	235.840	57	4.138		
	Total	1217.573	59			
Pollen equatorial axis	Between groups	588.933	2	294.467	177.465	0.000
	Within groups	94.580	57	1.659		
	Total	683.513	59			
Pollen colpus length	Between groups	1162.133	2	581.067	238.554	0.000
	Within groups	138.840	57	2.436		
	Total	1300.973	59			
Pollen colpus width	Between groups	2.533	2	1.267	7.648	0.001
	Within groups	9.440	57	0.166		
	Total	11.973	59			
Nutlet length	Between groups	5.033	2	2.517	198.409	0.000
	Within groups	0.723	57	0.01268		
	Total	5.756	59			
Nutlet width	Between groups	0.833	2	0.417	52.521	0.000
	Within groups	0.452	57	0.007933		
	Total	1.286	59			

TABLE 5. Means in homogeneous subsets for quantitative micromorphological characters of *Lallemantia* species in Turkey. Subset refers to the designation of homogeneous groups by the Tukey test between means. Means within the same subset do not significantly differ from each other (uses harmonic mean sample size = 30,000)

Character	Species	N	Subset for alpha = 0.05		
			1	2	3
Pollen polar axis	*L. peltata*	50	30.30		
	L. iberica	50		35.50	
	L. canescens	50			40.10
	Sig.		1.00	1.00	1.00
Pollen equatorial axis	*L. peltata*	50	22.00		
	L. iberica	50		23.30	
	L. canescens	50			29.30
	Sig.		1.00	1.00	1.00
Pollen colpus length	*L. peltata*	50	26.30		
	L. iberica	50		29.80	
	L. canescens	50			36.80
	Sig.		1.00	1.00	1.00
Pollen colpus width	*L. peltata*	50		1.80	
	L. iberica	50	1.30		
	L. canescens	50	1.60	1.60	
	Sig.		0.06	0.274	
Nutlet length	*L. peltata*	50	3.50		
	L. iberica	50		3.75	
	L. canescens	50			4.30
	Sig.		1.00	1.00	1.00
Nutlet width	*L. peltata*	50	1.50		
	L. iberica	50		1.75	
	L. canescens	50	1.50		
	Sig.		1.00	1.00	

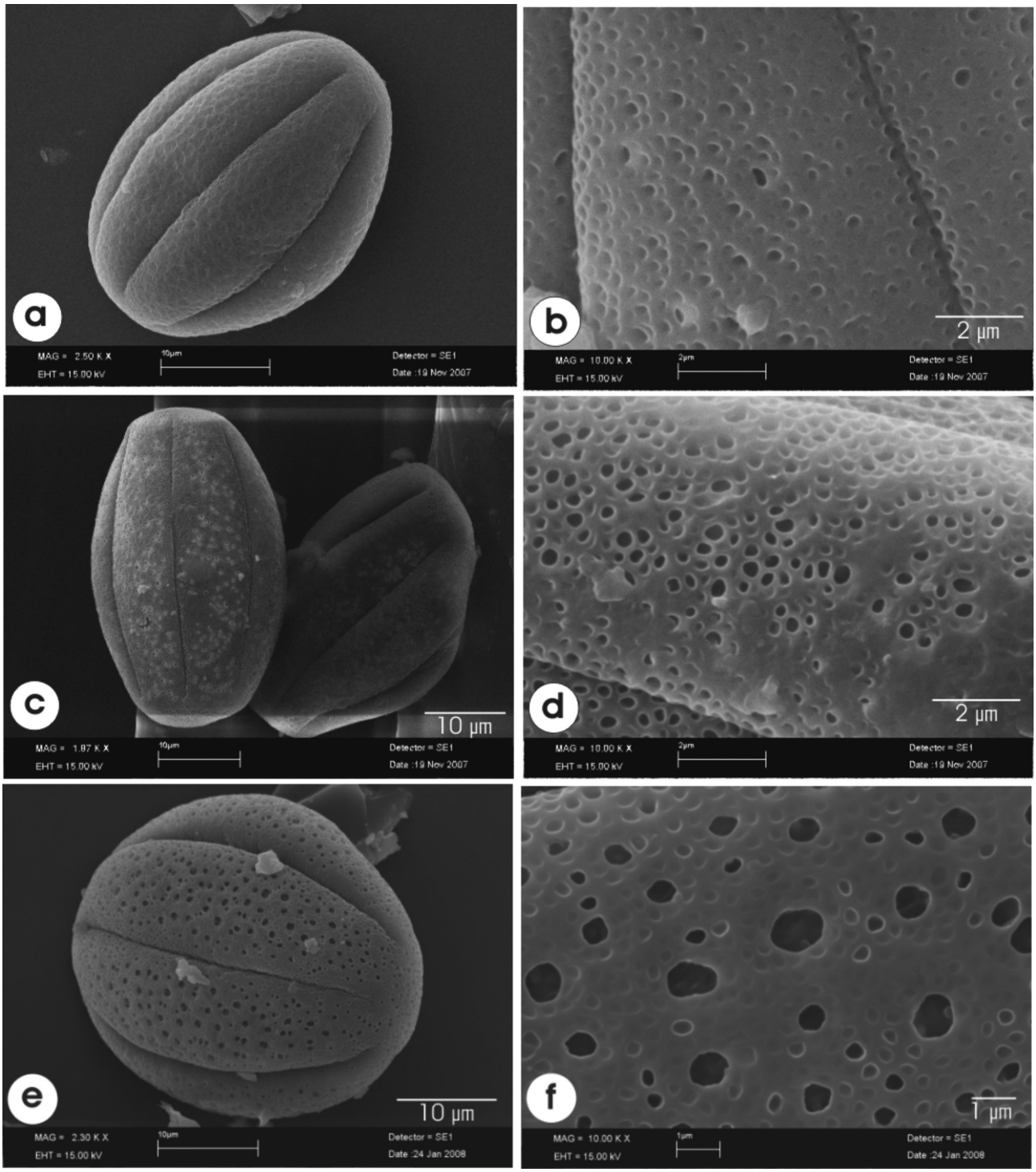

Fig. 1. General appearance (left) and surface details (right) of pollen grains of *Lallemantia* species. (**a**, **b**) *L. peltata*, (**c**, **d**) *L. iberica*, (**e**, **f**) *L. canescens*.

P × E ranges are 27.4–45.4 × 20.1–32.1 µm, and the P/E ratio is 1.2–1.7. Colpus length is 24.1–41.0 µm and colpus width is 0.8–3.0 µm. Pollen grain shape is prolate to prolate-spheroidal, with a rounded outline in polar view. Two pollen types are distinguished on the basis of exine sculpturing: reticulate-foveolate, and microreticulate which sometimes tends towards a bireticulum with differentiated

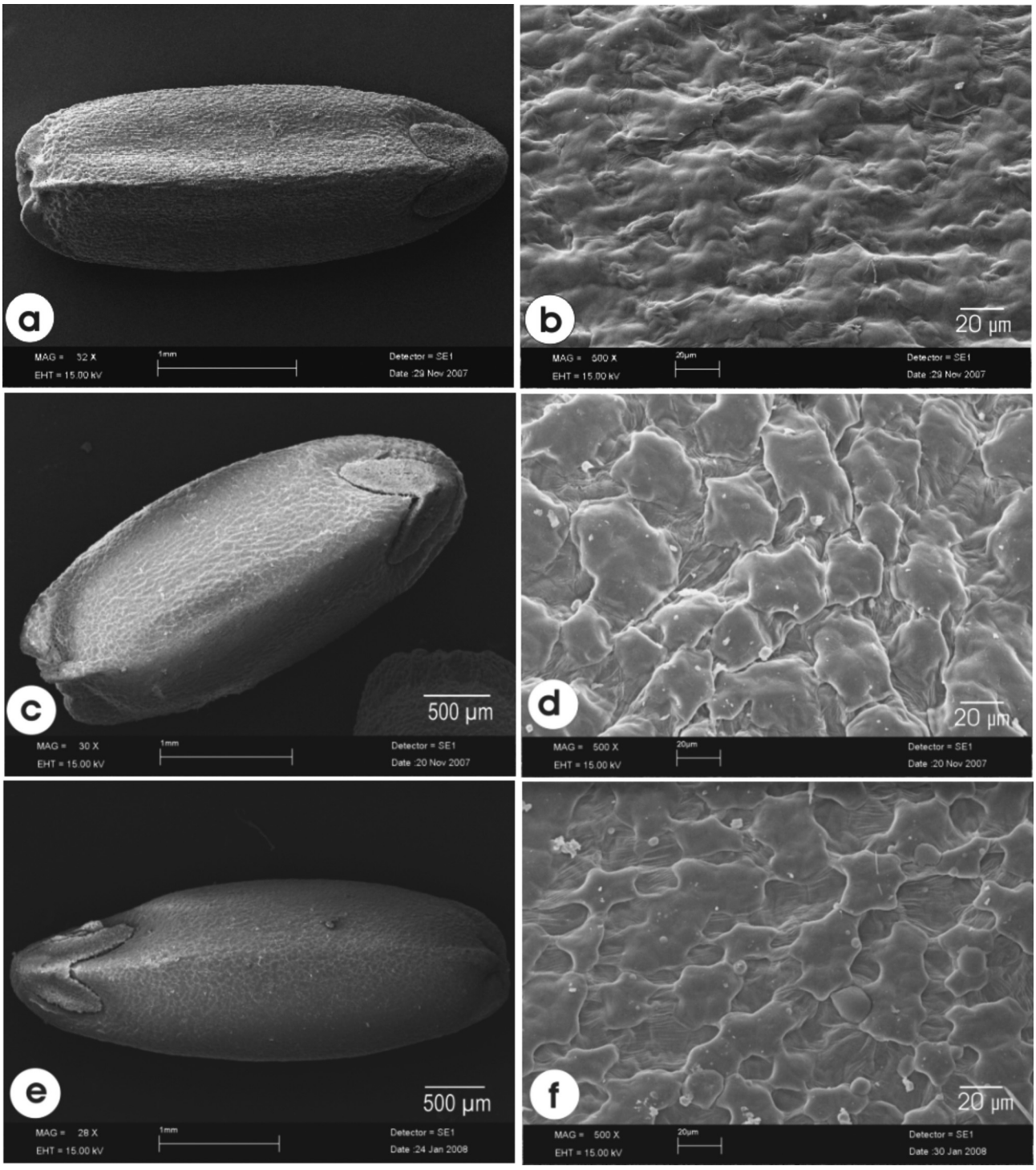

Fig. 2. General appearance (left) and surface details (right) of nutlets of *Lallemantia* species. (**a**, **b**) *L. peltata*, (**c**, **d**) *L. iberica*, (**e**, **f**) *L. canescens*.

traces of a secondary reticulum. The exine sculpturing of the apocolpium is perforate.

Pollen grains of *L. peltata* are radially symmetrical, isopolar, zonohexacolpate and prolate-subprolate in shape. The dimension ranges are 27.4–35.0 µm polar length, 20.2–25.3 µm equatorial width, 24.1–29.3 µm colpus length and 0.8–3.0 µm colpus width. The exine is microreticulated and tending towards a bireticulum with differentiated traces of a secondary reticulum, with

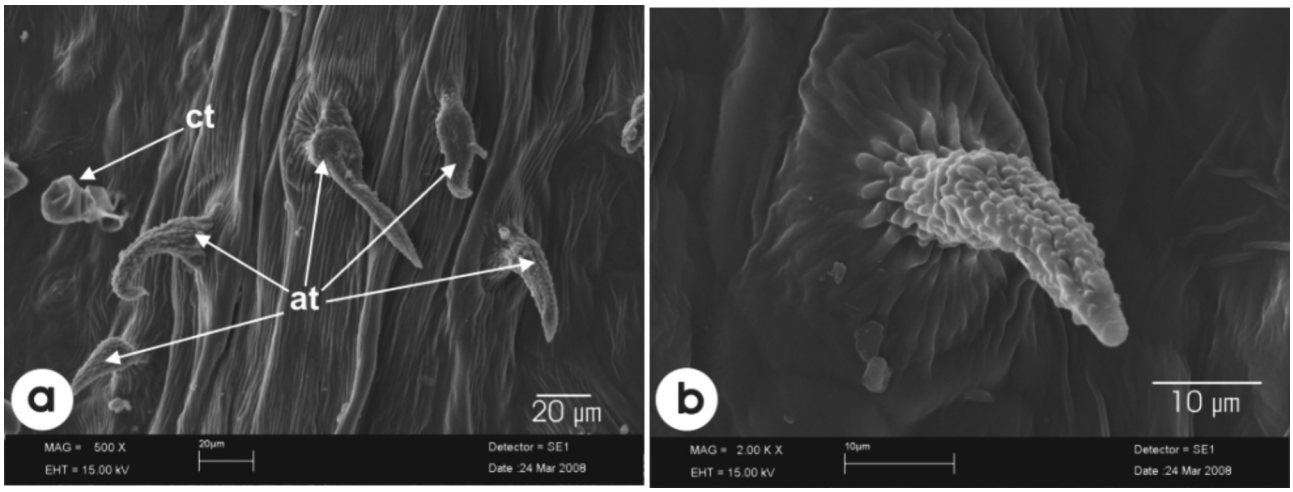

Fig. 3. Representative trichomes of *Lallemantia* species. (**a**) Showing capitate and acicular trichomes on *L. peltata*, (**b**) Papillar protuberances on acicular trichome of *L. iberica*. Ct – capitate trichome; at – acicular trichomes.

crowded puncta clearly associated into groups of 9–14 at the equator. The apocolpium of the exine sculpturing is perforate (Fig. 1a,b).

Pollen grains of *L. iberica* are radially symmetrical, isopolar, zonohexacolpate and prolate in shape. The dimension ranges are 32.3–40.2 µm polar length, 20.1–25.2 µm equatorial width, 26.7–34.5 µm colpus length and 0.8–1.6 µm colpus width. The exine is reticulated, with crowded puncta clearly associated into groups of 9–14 at the equator. The apocolpium of the exine sculpturing is perforate (Fig. 1c,d).

Pollen grains of *L. canescens* are radially symmetrical, isopolar, zonohexacolpate and prolate to prolate-spheroidal in shape. The dimension ranges are 35.0–45.4 µm polar length, 24.7–32.1 µm equatorial width, 33.0–41.0 µm colpus length and 1.0–2.6 µm colpus width. The exine is reticulate-foveolate at the equator. The apocolpium of the exine sculpturing is perforate (Fig. 1e,f).

The results of nutlet morphological study are presented in Tables 2 and 3, and representative nutlets of each species are illustrated in Figure 2. Nutlets of species of the genus *Lallemantia* in Turkey are black, glabrous and oblong-triangular in shape, with V-shaped areoles 3.20–4.40 mm long and 1.30–1.90 mm wide. The nutlet surface is verrucate or verrucate-rugulate, with 1–5 regular or irregular warts 10–40 µm in size, sometimes associated in 2 to 4 groups per μm^2.

Statistical analysis of the quantitative micromorphological characters shows the differences in pollen and nutlet characters between the three species to be significant (Tabs. 4, 5).

Nutlets of *L. peltata* are black, 3.20–3.75 mm long and 1.30–1.70 mm wide, and oblong-triangular in outline. The surface is verrucate-rugulate, with 1 or 2 regular warts (10–20 µm) per μm^2 (Fig. 2a,b). Those of *L. iberica* are black, 3.65–4.00 mm long, 1.60–1.90 mm wide, and triangular-oblong in outline. The surface is verrucate, with 4 or 5 irregular warts (25–30 µm) per μm^2 (Fig. 2c,d). Nutlets of L. canescens are black, 4.00–4.40 mm long, 1.40–1.60 mm wide, and narrowly triangular-oblong in outline. The surface is verrucate, with 3 or 4 irregular warts (25–40 µm) per μm^2, sometimes associated in 2 to 4 groups (Fig. 2e,f).

Capitate and acicular trichomes are seen on the stems, leaves, calyx and bracts of the studied *Lallemantia* species. There are no discernible differences in the distribution and types of trichomes between the three *Lallemantia* species. Capitate trichomes have a 1–2-celled stalk and a one-celled head. Acicular trichomes are 1–4-celled and densely covered by papillae visible by LM as well; the ornamentation of the acicular trichomes is baculate (Fig. 3).

DISCUSSION

Lamiaceae is divided into two main groups based on pollen characteristics such as aperture number and number of nuclei in shed pollen (Erdtman, 1945). The first group comprises the subfamily Lamioideae, and the second group contains the subfamily Nepetoideae (Cantino and Sanders, 1986). Aperture number has been considered a useful character to define the subfamily Nepetoideae. This subfamily is characterized by hexacolpate pollen grains with three nuclei at maturity (Erdtman, 1945; Cantino, 1992). The genus *Lallemantia*, included in subfamily Nepetoideae, tribe Mentheae, has hexacolpate pollen grains as in the other genera of subfam-

ily Nepetoideae (Harley et al., 1992; Jamzad et al., 2000). However, some species belonging to the genera *Glechoma* L., *Hymenocrater* Fisch. and C.A. Mey. and *Meehania* Britton from tribe Mentheae, subtribe Nepetinae, have predominantly hexacolpate, sometimes mixed with some octocolpate grains (Moon et al., 2008b). All pollen grains of *Lallemantia* in this study are hexacolpate.

The pollen of *L. cansecens* are slightly larger than those of *L. iberica* and *L. peltata*, but the pollen grains of the three species show similar characteristics in relation to shape, colpus size and aperture types (Tab. 3). The polar outlines of the pollen are more or less circular in the studied taxa. In equatorial view the shapes are prolate-subprolate in *L. peltata*, prolate in *L. iberica*, and prolate-prolate spheroidal in *L. canescens*. Although more or less uniform between taxa, the shapes sometimes vary within a taxon. These findings mean that differences in the shape of *Lallemantia* pollen grains are neither particularly significant nor useful in separating the species. Other studies also suggest that differences in pollen shape and size mostly have very limited or no taxonomic value in the family Lamiaceae (Moon and Hong, 2006; Kaya and Kutluk, 2007; Moon et al., 2008a,b).

Useful variations in exine ornamentation were determined in *Lallemantia* species. The exine clearly has diagnostic value in distinguishing *L. canescens* from the other two species. In *L. canescens* it is reticulate-foveolate; in *L. iberica* and *L. peltata* it is reticulated with crowded puncta associated in groups of 9–14 at the equator. Pollen exine sculpturing is useful for ascertaining relationships among species (Brochmann, 1992), and in Lamiaceae its usefulness in infrageneric and even interspecific classification is confirmed in many studies (Oybak-Dönmez et al., 1999; Moon and Hong, 2006; Kaya and Kutluk, 2007; Moon et al., 2008a,b; Akgül et al., 2008; Dinç and Öztürk, 2008). Besides reticulation, which is the most common type of sculpture pattern of Lamiaceae, a foveolate pattern is recorded for some *Sideritis* species of the subfamily Lamioideae (Abu-Assab and Cantino, 1994) and for the only Turkish endemic species, *Acinos troodi* (Post) Leblebici from the subfamily Nepetoideae, tribe Mentheae (Kaya and Kutluk, 2007). In the present study this pattern is determined for *L. canescens* in Nepetoideae, tribe Mentheae for the second time, and in tribe Mentheae, subtribe Nepetinae for the first time.

The sexine ornamentation in the Nepetinae is microreticulate, perforate or bireticulate (Moon et al., 2008b). Recent molecular data show *Lallemantia* to be closely related to the genera *Agastache* Clayton ex Gron., *Dracocephalum* L., *Hyssopus* L. and *Glechoma* L. in subtribe Nepetinae (Trusty et al., 2004). Palynologically, *L. peltata* shares microreticulate ornamentation with secondary tectal connections with some *Dracocephalum* species, and *L. royleana* shares a bireticulate pattern with the genus *Agastache*. A simple microreticulate pattern is found in some *Dracocephalum* species and *Glechoma hederacea* (Moon et al., 2008b) as in *L. Iberica* according to the present study. With the reticulate-foveolate pattern defined in *L. canescens*, the sexine ornamentation variation in subtribe Nepetinae is widened.

Historically, *Lallemantia* was classified as a subgenus of *Dracocephalum* by Budantsev (1993), but some morphological features and several molecular studies clearly favor *Lallemantia* as an independent genus (Harley et al., 2004; Trusty et al., 2004). Interestingly, however, *Dracocephalum* and *Lallemantia* show variation of sexine ornamentation while the other taxa produce basically the same sexine ornamentation type at the generic level in tribe Mentheae, subtribe Nepetinae. *Lallemantia peltata* possesses the same sexine ornamentation as *Dracocephalum*, microreticulate tending towards a bireticulum with differentiated traces of a secondary reticulum, whereas *Lallemantia royleana* shares bireticulate sexine ornamentation with *Nepeta* (Moon et al., 2008b). The present study supports variation of sexine ornamentation in the genus *Lallemantia* as well. In the studied taxa, exine ornamentation varies from microreticulate to reticulate-foveolate. However, the secondary reticulum trace can be seen in *L. peltata* but not in *L. canescens*.

External nutlet characters are generally of limited taxonomic value in the tribe Mentheae. However, nutlet surface sculpturing patterns as seen by SEM show a wide range of variation and have diagnostic value for species recognition (Jamzad et al., 2000, 2003; Moon and Hong, 2006; Kaya and Dirmenci, 2008). In the studied *Lallemantia* species as well, external nutlet characters show homogeneity while nutlet surface sculpturing patterns are clearly a good character for interspecific classification. The nutlet surface is verrucate-rugulate in *L. peltata* and verrucate in *L. iberica* and *L. canescens*. In *L. iberica* the warts are 4 or 5 (25–30 μm) per μm^2, and in *L. canescens* they are 3 or 4 (25–40 μm) per μm^2 and sometimes associated in 2 to 4 groups.

Trichome micromorphology has taxonomic value for interspecific and infrageneric classification in some genera of the family Lamiaceae (Navarro and El Oualidi, 2000; Jurišić Grubešić et al., 2007; Dinç and Öztürk, 2008), but not for interspecific classification of the genus *Lallemantia*. However, the papillar protuberances on the acicular hairs may have diagnostic value for infrageneric classification of Lamiaceae; they have not been emphasized in previous studies in other genera.

To summarize, trichome micromorphology and distribution has no taxonomic value in separating the three studied species. Pollen and nutlet shapes and sizes are more or less similar, but their surface ornamentation appears to have taxonomic value. However, pollen surface characteristics show no correlation with nutlet surface characteristics. While the annual species *L. iberica* and *L. peltata* are more similar in pollen characteristics, *L. iberica* and the perennial *L. canescens* are close with regard to nutlet characteristics. Nutlet surface characteristics are more concordant with bract morphology, the most important morphological character in interspecific classification of the genus *Lallemantia*.

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