Pollen morphology of *Lathyrus* (Leguminosae) taxa belonging to *Lathyrus*, *Orobastrum* and *Cicerula* sections from Turkey

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Abstract The pollen morphology of 20 wild taxa belonging to *Lathyrus* (Syn: *Eulathyrus*), *Orobastrum* (Taub.) Boiss. and *Cicerula* (Medic.) Gren. & Godr. sections of *Lathyrus* L. grown in Turkey (*L. rotundifolius* Wild. subsp. *miniatus* (Bieb. ex Steven) P.H. Davis, *L. grandiflorus* Sibth. & Sm., *L. saxatilis* (Vent.) Vis., *L. vinealis* Boiss. & Noë, *L. inconspicuus* L. var. *inconspicuus*, *L. inconspicuus* var. *stenophyllus* (Boiss.) Rech. f., *L. tauricola* P.H. Davis, *L. woronowii* Bornm., *L. hierosolymitanus* Boiss., *L. cassius* Boiss., *L. gorgoni* Parl. var. *gorgoni*, *L. pseudo-cicera* Pamp., *L. sativus* L., *L. blepharicarpus* Boiss., *L. stenophyllus* Boiss. & Heldr., *L. belinensis* Maxted & Goyder, *L. phaselitanus* Hub.-Mor. & P.H.Davis, *L. chrysanthus* Boiss., *L. chloranthus* Boiss., and *L. trachycarpus* (Boiss.) Boiss were examined by light microscopy (LM) and scanning electron microscopy (SEM) in this study. The pollen grains were 3-zonocolporate, spheroidal, subprolate, and prolate ($P/E = 0.99\text{--}1.48$) types, and were medium in size (equatorial view: rectangular or elliptical-obtuse-convex; polar view: circular, triangular and quinquangular-obtuse-convex). The smallest pollen grains belonged to *L. tauricola* ($P = 30.94/E = 31.20$) and the largest to *L. grandiflorus* ($P = 50.60/E = 36.40$). The ornamentation was reticulate and reticulate-granulate in the mesocolpium, and usually psilate in the apocolpium. Some photographs included in this work were taken using both LM and SEM.

Keywords *Cicerula* · *Lathyrus* · *Orobastrum* · Pollen morphology · Turkey

Introduction

Lathyrus L. is the largest genus in the tribe Fabaceae of the family Fabaceae, with about 200 known species worldwide. The eastern Mediterranean region is the main centre of diversity for the genus, which is less diversified in North and South America (Bässler 1980; Kupicha 1983; Simola 1986). In Turkey, 66 species and 76 taxa of *Lathyrus* have been identified (Davis 1970, 1988; Güneş and Özhatay 2000). The endurance of *Lathyrus* against drought (e.g., *L. sativus*, *L. ochrus*) is well known, and the economic value of this is high. *L. sylvestris* is utilised to prevent erosion in the disrupted and burned-down fields of America (Whyte et al. 1953; Yamamoto and Fujiwara 1984). The roots of *L. tuberosus* are consumed as food in the East Anatolian region of Turkey, *L. ochrus* and *L. sativus* are used for agricultural processes in Turkey (Güneş 2006), and approximately 33 species are used for ornamental purposes (Campbell 1997).

In Turkey, the following characteristics are seen in *Lathyrus* species: perennial, procumbent to climbing; angled or winged stems; leaves are tendrillous, with leaflets that are one-paired, and either broadly elliptical or linear, with parallel veins and semi-sagittate stipules; racemes are comprised of three or many flowers, with a twisted style; legumens are glabrous, with the upper suture not being two winged. *Orobastrum* characteristics are annual; procumbent to climbing; angled or sometimes have very narrowly winged stems; tendrillous or aristate leaves; leaflets are one-paired or several-paired, linear to elliptic, with parallel veins; peduncles are one-flowered; and legumens are glabrous or pubescent, with the upper suture not being 2-winged. *Cicerula* is the largest and most difficult section of *Lathyrus* in Turkey. In this section the flower colour is very important for identification, and often changes

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drastically on drying (brick-red flowers turn a bluish-purple), making field notes on flower colour essential. This group is very diverse and problematic in Turkey (Davis 1970). Section *Cicerula* contains approximately 25 annual species throughout middle and southern Europe, southwest Asia and north Africa (Post 1932; Fedchenko 1948; Ball 1968; Davis 1970, 1988; Dakijordanov 1976; Meikle 1977; Townsend and Guest 1977; Rechinger 1979; Tutin and Heywood 1981; Zohary 1987; Güneş and Özhatay 2000). The species in this group have very well-framed characteristics: an annual procumbenec to climbing; stems that are winged in the upper part; leaves are tendrillous or rarely aristate; leaflets are one-paired, elliptic to linear, with parallel to pinnate-parallel veins, and stipules are semi-sagittate; peduncles have one to several flowers with a style that is usually twisted; the colour of the flowers varies (bright red, brick red, soft yellow, orange, gingery orange, pink, lilac or light purple, sky blue, rose or clear pink with purplish, bluish purple, golden, bright yellow or sulphur, wine red); and legumens are glabrous or hairy, with the upper suture being two-winged or wingless (Davis 1970).

The pollen morphology of some taxa belonging to the *Lathyrus* species has been studied by various researchers, especially in Turkey, but also throughout the world. The pollen morphology of the taxa in Turkey has been determined for *L. digitatus* Aytug et al. (1971), *L. undulatus*, *L. sylvestris* and *L. ochrus* (Günes and Cırpıcı 1998), *L. pratensis*, *L. layardii*, *L. laxiflorus* subsp. *laxiflorus*, *L. laxiflorus* subsp. *angustifolius* and *L. czeczottianus* (Günes and Aytug 2010), *L. annuus*, *L. cicera*, *L. gorgoni* var. *pilosus* and *L. hirsutus* (Günes and Cırpıcı 2010), *L. niger*, *L. palustris* subsp. *palustris*, *L. tuberosus*, *L. sphaericus*, *L. setifolius*, *L. clymenum*, *L. nissolia*, *L. aphaca* var. *aphaca*, *L. aphaca* var. *affinis* and *L. aphaca* var. *biflorus* (Günes 2011b), and *L. pallescens*, *L. brachypterus*, *L. haussknechtii*, *L. karsianus*, *L. satdaghensis*, *L. nivalis*, *L. atropatanus*, *L. armenus*, *L. cyaneus* var. *cyaneus*, *L. cyaneus* var. *pinnatus*, *L. digitatus*, *L. tukhtensis*, *L. variabilis*, *L. spatulatus*, *L. elongatus*, *L. cilicicus* and *L. boissieri* (Günes 2011a). Apart from in Turkey, the morphological features of pollen have been determined for *L. niger* (Gapotchka and Chamara 1972; Gapotchka 1974), *L. palustris* (Faegri and Iversen 1989) in Russia; *L. sylvestris*, *L. pratensis*, *L. maritimus*, *L. nissolia* and *L. montanus* (Moore et al. 1991) in France; *L. emodii*, *L. cicera*, *L. humulis* and *L. pratensis* (Perveen and Kaiser 1998) in Pakistan; *L. grandiflorus*, *L. latifolius*, *L. sylvestris*, *L. tuberosus* (Tosheva et al. 2004), *L. alpestris*, *L. aureus*, *L. linifolius*, *L. niger*, *L. palustris*, *L. transsilvanicus*, *L. venetus* and *L. vernus* (Tosheva and Tonkov 2005), and *L. digitatus*, *L. filiformis*, *L. pallescens*, *L. panicii* and *L. pannonicus* (Tosheva and Tonkov 2007) in Bulgaria.

The *Lathyrus* group in Turkey involves five taxa in total, with one taxon that is endemic (*L. undulatus*). Section *Orobastrum* contains eight taxa, two of which are endemic (*L. tauricola* and *L. woronowii*), and the *Cicerula* section contains 18 taxa, with four endemic taxa (*L. lycicus* Boiss., *L. belinensis*, *L. phaselitanus*, *L. trachycarpus*). The pollen of some taxa belonging to *Lathyrus*, *Orobastrum* and *Cicerula* sections have been analysed: *L. tuberosus*, *L. undulatus*, *L. sylvestris*, *L. sphaericus*, *L. setifolius*, *L. annuus*, *L. cicera*, *L. gorgoni* var. *pilosus* and *L. hirsutus* (by Günes and Cırpıcı 1998, 2010; Günes 2011b). These researchers have provided information about the pollen type (3-zonocolporate), pollen shape (spheroidal, subprolate, prolate), structure (tectate infrastructure) and ornamentation (reticulate-granulate) of the taxa belonging to the *Cicerula* section. Furthermore, Moore et al. (1991), Güneş and Aytug (2010) and Günes (2011a, b) also noted that the endexine thickens two to three times around the colpus and the porus, and forms a large costae formation.

Therefore, the aim of this study is to determine the pollen morphological properties of 20 *Lathyrus* taxa belonging to *Lathyrus*, *Orobastrum* and *Cicerula* sections. The secondary aim is to use these properties in the identification of species. In this study, the morphological features of the pollen of 17 taxa, with the exception of *L. inconspicuus* var. *inconspicuus*, *L. saxatilis* and *L. chloranthus* (Kahraman et al. 2012), distributed throughout Turkey, were examined for the first time.

Materials and methods

Twenty taxa of *Lathyrus* were collected from their natural habitats in Turkey between 2004 and 2011 (Table 1). Two taxa (*L. marmoratus* Boiss. & Bl. and *L. lycicus*) were not collectable from their natural habitats, and there was no record of any examples in any of the herbariums examined. All of the collected specimens were identified and deposited in the Herbarium of Kafkas University, Faculty of Arts and Sciences, in the Department of Biology. The pollen was analysed in preparations made using the non-acetolysis method (Wodehouse 1959) under a light microscope. Except for the taxa *L. grandiflorus*, *L. sativus*, *L. belinensis* and *L. phaselitanus*, for each taxon the pollen belonging to the flowers collected from at least two localities was used. Ten characteristics of the pollen were examined under a magnification of 1,000×: polar diameter (*P*), equatorial diameter (*E*) [measured by 400 times magnitude], colpus width (clt; colpus width was measured in regions close to the porus), porus length (plg), porus width (plt), one edge of the polar triangle (*t*), exine thickness, intine thickness and costae. The structural (exine) and sculptural (exine ornamentation) forms were also shown (Table 2). The

Table 1 The specimens examined and their distribution throughout the world

Sections	Taxa	Distribution in the world	Locality
<i>Lathyrus</i>	<i>L. rotundifolius</i> subsp. <i>miniatus</i>	Caucasia, N. Iraq, N. Iran	A8 Bayburt: Bayburt-Gümüşhane road, Akşar village, field side, 1,614 m, 15.07.2009, <i>F. Güneş</i> 2466. A9 Kars: Kars-Susuz road, 8 km, field side, 1,780 m, 19.06.2004, <i>F. Güneş</i> 16. B9 Bitlis: Mountain Kirkor, 1,853 m, 15.06.2008, <i>F. Güneş</i> 1851
	<i>L. grandiflorus</i>	Greece, S. Balkans, Macedonia, S. Italy, Sicily and W. Anatolia	A1(A) Balıkesir: Erdek, Ocaklar village, 65 m, 13.06.2011, <i>F. Güneş</i> 2749
<i>Orobastrum</i>	<i>L. saxatilis</i>	S. Europe, Crimea, Cyprus, Syrian Desert, Cyrenaica	C3 Isparta: Aksu, around Zindan Cave, 18.06.2011, <i>F. Güneş</i> 2761. Kovada Lake area, 18.06.2011, <i>F. Güneş</i> 2769
	<i>L. vinealis</i>	N. Iraq, W. Iran. E. Anatolia	B9 Bitlis: Bitlis-Baykan road, 10 km, roadside, 1,419 m, 09.05.2009, <i>F. Güneş</i> 2105. C7: Urfa: Diyarbakır-Urfa road, border of Urfa, 1,105 m, 11.05.2009, <i>F. Güneş</i> 2142
	<i>L. inconspicuus</i> var. <i>inconspicuus</i>	S. Europe, SW and C. Asia	A9 Kars: Subatan village, cultivated fields, 1,620 m, 06.06.2006, <i>F. Güneş</i> 140. B9 Bitlis: Bitlis-Baykan road, 10 km, roadside, 1419 m, 09.05.2009, <i>F. Güneş</i> 2106. C7 Urfa: Siverek-Bucak road, Kalnağaç village, fields, 780 m, 12.05.2009, <i>F. Güneş</i> 2176
	<i>L. inconspicuus</i> var. <i>stenophyllus</i>	Syria, NW and C. Iran, E. Afghanistan. SE Anatolia	C7 Urfa: Siverek-Bucak road, Kalnağaç village, fields, 780 m, 12.05.2009, <i>F. Güneş</i> 2177
	<i>L. tauricola</i> (end)	S. Anatolia (Isparta)	C3 Isparta: Aksu, around Zindan Cave, 1,209 m, 12.06.2009, <i>F. Güneş</i> 2344. Kovada Lake area, 1,058 m, 18.06.2011, <i>F. Güneş</i> 2768
	<i>L. woronovii</i> (end)	NE. Anatolia (Çoruh valley)	A9 Artvin: Çoruh valley, Yusufeli road, 511 m, 19.05.2009, <i>F. Güneş</i> 2190. Yusufeli-Sukavuşumu, 430 m, 23.05.2009, <i>F. Güneş</i> 2206
	<i>L. hierosolymitanus</i>	S. Anatolia, W. Syria, N. Egypt, Cyrenaica E. Medit. element	C6: Osmaniye: Osmaniye-Toprakkale road 8 km, cultivated and uncultivated fields, 50 m, 18.04.2009, <i>F. Güneş</i> 2006. Hatay: Hatay-Kışlak road 2 km to the parting way of Kışlak, 160 m, 05.07.2011, <i>F. Güneş</i> 2776
<i>Cicerula</i>	<i>L. cassius</i>	S. and SE Anatolia, W. Syria, Cyprus, N. Iraq E. Medit. element	B7 Elazığ: Elazığ-Bingöl road, water channel edges, 860 m, 11.07.2008, <i>F. Güneş</i> 1972. C5 Mersin: Silifke-Taşucu road 4 km, İmamuşağı village, 21.04.2009, <i>F. Güneş</i> 2038. C8 Diyarbakır: Ovabağ Zelyağı village, roadside, 735 m, 11.05.2009, <i>F. Güneş</i> 2135
	<i>L. gorgoni</i> var. <i>gorgoni</i>	S. and SE Anatolia, Sicily, Sardinia, Cyrenaica, N. Sinai, W. Syria, Cyprus, N. Iraq. E. Medit. element	C6 Hatay: Yayladağ, roadside and uncultivated fields, 393 m, 19.04.2009, <i>F. Güneş</i> 2022. C8 Diyarbakır: Ovabağ Özyar village, road and field sides, 735 m, 11.05.2009, <i>F. Güneş</i> 2132
	<i>L. pseudo-cicera</i>	SE Anatolia, Cyrenaica, N. Egypt, Palestine, Syrian Desert, N. Iraq, W. Iran. Ir.-Tur. element	C7 Urfa: Siverek-Urfa road, Karakoyun village, roadside, 12.05.2009, <i>F. Güneş</i> 2184. C8 Diyarbakır: Ovabağ Zelyağı village, roadside, 735 m, 11.05.2009, <i>F. Güneş</i> 2137
	<i>L. sativus</i>	Widespread except in the NE, S. and C. Europe, N. Africa, SW Asia	B8 Muş: Malazgirt, cultivated fields, 1,511 m, 15.06.2008, <i>F. Güneş</i> 1852
	<i>L. blepharicarpus</i>	S. Anatolia, W. Syria, Cyprus. E. Medit. element	C5 Mersin: Mersin-Silifke road 45 km, oak scrubs, 20.04.2009, <i>F. Güneş</i> 2035. C6 Hatay: Belen-Hatay road 5 km, forest side and roadside, 565 m, 18.04.2009, <i>F. Güneş</i> 2008
	<i>L. stenophyllus</i>	S. Anatolia, Islands, Crete & W. Syria, E. Medit. element	C3 Antalya: Faselis National Park, 23.04.2009, s.l., <i>F. Güneş</i> 2066. C4 Mersin: Taşucu-Aydıncık road, Akdere village, under and open forest, 53 m, 21.04.2009, <i>F. Güneş</i> 2041

Table 1 continued

Sections	Taxa	Distribution in the world	Locality
	<i>L. belinensis</i> (end)	S. Anatolia (Antalya)	C3 Antalya: Kemer-Kumluca road 45 km, roadside and open forest, 375 m, 23.04.2009, <i>F. Güneş</i> 2071
	<i>L. phaselitanus</i> (end)	S. Anatolia (Antalya)	C3 Antalya: Faselis National Park, s.l., 23.04.2009, <i>F. Güneş</i> 2068
	<i>L. chrysanthus</i>	SE Anatolia, Lebanon, Syrian Desert. Ir.-Tur. element	C7 Urfa: Siverek-Bucak road, Kalınağaç village, border of cultivated and uncultivated fields, 780 m, 12.05.2009, <i>F. Güneş</i> 2175. C8 Diyarbakır: Mountain Karacadağ, field side and volcanic rockys, 1,100 m, 11.05.2009, <i>F. Güneş</i> 2155
	<i>L. chloranthus</i>	Inner and E. Anatolia, N. Iraq, Iran, Armenia. Ir.-Tur. element	A8 Bayburt: Bayburt-Gümüşhane road, Akşar village, field side, 1,614 m, 15.07.2009, <i>F. Güneş</i> 2465. B9 Ağrı: Hamur-Tutak road 8 km, riverside, 1,624 m, 07.07.2009, <i>F. Güneş</i> 2444
	<i>L. trachycarpus</i> (end)	SE Anatolia (Karacadağ)	C7 Urfa: Siverek-Bucak road, Kalınağaç village, border of cultivated and uncultivated fields, 780 m, 12.05.2009, <i>F. Güneş</i> 2180

City names and their grids are given in bold

arithmetic means, standard deviations and variations were calculated for each characteristic. The standard deviations for the characteristics that had no requirement for multiple measurements are not given. For SEM, the pollen grains were mounted onto stubs with double-sided adhesive tape and were then coated with gold. These coated pollen grains were then examined. The microphotographs were obtained using LEO 440 SEM at a magnification of 2,000–13,000 $\times$ and LM at 1,000 $\times$. The morphological descriptions of the pollen follow the terminology of Moore et al. (1991) and Punt et al. (1994).

Results

General remarks

The morphological characteristics of the pollen of 20 taxa belonging to sections *Lathyrus*, *Orobastrum*, and *Cicer-cula*, indicating a natural dispersion in Turkey, were studied. The characteristics were measured in preparations made using a non-acetolysis method, and their numerical values are given in Table 2. The pollen shape was found to be: spheroidal in *L. inconspicuus* var. *inconspicuus*, *L. inconspicuus* var. *stenophyllus*, *L. tauricola*, and *L. hierosolymitanus*; subprolate in *L. rotundifolius* subsp. *miniatus*, *L. saxatilis*, *L. vinealis*, *L. gorgoni* var. *gorgoni*, *L. pseudo-cicera*, *L. sativus*, *L. blepharicarpus*, *L. stenophyllus*, *L. belinensis*, *L. chrysanthus*, and *L. chloranthus*; subprolate to prolate in *L. trachycarpus*; and prolate in

L. grandiflorus, *L. woronowii*, and *L. cassius*. Descriptions of the pollen of these taxa are provided below:

L. rotundifolius subsp. *miniatus* (Table 2; Figs. 1a, b, 2a–c)

Pollen type: 3-zonocolporate.

Pollen shape: subprolate *P/E*: 1.21

Dimensions: medium size ($P \times E = 41.29 \times 34.11 \mu\text{m}$).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: long, straight, nearly reaching the poles, narrow, deep, with acute ends, borders distinct, broader on pori, clg: $33.11 \mu\text{m}$, clt: $2.12 \mu\text{m}$; endoapertures-pori: large, borders distinct, lalongate, with an annulus (thickness sexine) and costae (thickness nexine), plg: $8.59 \mu\text{m}$, plt: $11.68 \mu\text{m}$ and plg/plt: 0.74.

Outlines: equatorial view rectangular-obtuse-convex; polar view circular to triangular-obtuse-convex.

Ornamentation: reticulate-slightly granulate, reticules big, different in size and shape in the mesocolpium, decreasing towards the apocolpium and colpus. The polar area and colpus area are psilate.

Ex/int: $\cong 1/2$

Exine: $\cong 1.14 \mu\text{m}$.

L. grandiflorus (Table 2; Figs. 1c, d, 2d–f)

Pollen type: 3-zonocolporate.

Pollen shape: prolate *P/E*: 1.39

Dimensions: medium size ($P \times E = 50.60 \times 36.40 \mu\text{m}$).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: long, straight, wide, deep, with acute ends, the borders very distinct, broader on pori, clg: $36.48 \mu\text{m}$, clt:

Table 2 Pollen characteristics of the examined taxa

Sections	Taxa	P	E	P/E	Ex/int	clg	clt	plg	plt	plg/plt	t	Structure	Sculpture	References
<i>Lathyrus</i>	<i>L. tuberosus</i>	M σ var.	34.69 ± 1.14 11–13	31.72 ± 1.26 10–12	1.09 spheroidal	$\cong 1/1$	24.51 ± 1.61 19–25	3.50 ± 1.19 1–5	9.05 ± 0.80 6–9	9.60 ± 1.16 7–10	0.94 ± 13.04	Tectate infrastructurae	Pollen slightly reticulate, perforate-foveolate, slightly distinct and irregular	(Günes and Cirpici 1998)
	<i>L. rotundifolius</i> subsp. <i>miniatius</i>	M σ var.	41.29 ± 2.72 14–17	34.11 ± 1.18 12–14	1.21 subprolate	$\cong 1/2$	33.11 ± 1.93 26–33	2.12 ± 0.88 1–2.5	8.59 ± 0.60 6–10	11.68 ± 1.08 8–11	0.74 Non-measurable	Tectate infrastructurae	Mesocollipium reticulate, reticules big and slightly distinct, apocollipium psilate	
	<i>L. undulatus</i>	M σ var.	40.44 ± 3.94 31–54	35.20 ± 3.61 22–39	1.15 subprolate	$\cong 3/2$	27.68 ± 2.15 24–32	2.54 ± 0.49 1–4	8.50 ± 0.73 7–9	12.59 ± 1.27 10–16	0.68 ± 14	Tectate infrastructurae	Reticulate, reticules big and regular	(Günes and Cirpici 1998)
	<i>L. sylvestris</i>	M σ var.	42.84 ± 0.70 41–44	35.78 ± 0.88 34–38	1.20 subprolate	$\cong 1/2$	29.79 ± 1.50 28–34	3.07 ± 0.66 1–4	7.58 ± 0.51 6–9	9.01 ± 0.54 8–10	0.84 ± 18	Tectate infrastructurae	Reticulate, reticules very distinct, big, near apertures small and little distinct	(Günes and Cirpici 1998)
	<i>L. grandiflorus</i>	M σ var.	50.60 ± 1.82 18–21	36.40 ± 1.27 13–15	1.39 prolate	$\cong 1/2$	36.48 ± 1.80 30–36	3.69 ± 0.54 2–4	11.15 ± 0.80 8–11	13.95 ± 1.03 10–14	0.80 Non-measurable	Tectate infrastructurae	Mesocollipium reticulate, reticules distinct, big, apocollipium rare- perforate	
<i>Orobastrum</i>	<i>L. saxatilis</i>	M σ var.	37.24 ± 1.82 13–16	30.41 ± 1.82 10–13	1.22 subprolate	$\cong 2/1$	25.35 ± 1.78 20–25	Non-measurable	7.75 ± 0.99 5–9	12.12 ± 1.63 7–14	0.64 Non-measurable	Tectate infrastructurae	Mesocollipium reticulate- granulate, reticules distinct, big, apocollipium rare- foveolate	
	<i>L. vinealis</i>	M σ var.	36.49 ± 1.07 13–15	29.25 ± 1.62 10–12	1.25 subprolate	$\cong 1/1$	31.08 ± 1.04 25–29	5.68 ± 0.81 3–5	7.68 ± 0.71 6–8	12.97 ± 0.99 10–13	0.59 Non-measurable	Tectate infrastructurae	Mesocollipium reticulate, reticules medium, apocollipium almost psilate	
	<i>L. sphaericus</i>	M σ var.	33.96 ± 1.13 11–12	31.35 ± 1.45 10–12	1.08 spheroidal	$\cong 2/1$	26.35 ± 1.93 20–26	1.57 ± 0.55 1–2	8.40 ± 1.88 5–8	9.05 ± 0.76 6–9	0.93 Non-measurable	Tectate infrastructurae	Reticulate, reticules big or medium size, distinct, and regular	(Günes 2011b)
	<i>L. inconspicuus</i> var. <i>inconspicuus</i>	M σ var.	31.62 ± 1.20 11–13	30.58 ± 1.23 11–13	1.03 spheroidal	$\cong 1/1$	18.08 ± 1.18 14–18	2.37 ± 0.78 1–3	7.39 ± 0.57 6–7	8.78 ± 0.78 7–9	0.84 Non-measurable	Tectate infrastructurae	Mesocollipium concave, granulate, apocollipium almost psilate	
	<i>L. inconspicuus</i> var. <i>stenophyllus</i>	M σ var.	31.98 ± 1.19 12–13	30.99 ± 1.26 11–13	1.03 spheroidal	$\cong 1/1$	18.56 ± 1.77 12–18	2.85 ± 0.92 1–4	7.18 ± 0.57 5–7	8.76 ± 0.70 7–9	0.82 Non-measurable	Tectate infrastructurae	Mesocollipium concave, granulate, apocollipium almost psilate	
<i>L. tauricola</i>	<i>L. tauricola</i>	M σ var.	30.94 ± 1.68 11–14	31.20 ± 1.72 11–14	0.99 spheroidal	$\cong 2/1$	16.76 ± 1.12 13–17	4.17 ± 0.90 2–5	6.59 ± 0.77 5–7	8.48 ± 1.05 6–9	0.78 Non-measurable	Tectate infrastructurae	Mesocollipium concave, granulate apocollipium almost psilate	
	<i>L. woronowii</i>	M σ var.	35.78 ± 1.52 13–15	26.31 ± 0.84 10–11	1.36 prolate	$\cong 1/1$	26.93 ± 1.18 22–25	4.06 ± 0.57 3–4	9.05 ± 0.69 7–9	11.42 ± 0.95 8–12	0.79 Non-measurable	Tectate infrastructurae	Mesocollipium reticulate, reticules big and irregular, apocollipium slightly reticulate	
	<i>L. setifolius</i>	M σ var.	34.39 ± 0.96 11–12	30.33 ± 1.19 10–11	1.13 spheroidal	$\cong 1/1$	25.52 ± 1.59 19–25	2.96 ± 0.86 1–4	7.06 ± 0.64 5–7	11.34 ± 0.88 8–11	0.62 Non-measurable	Tectate infrastructurae	Reticulate, reticules distinct and medium size	(Günes 2011b)

Table 2 continued

Sections	Taxa	P	E	P/E	Ex/int	clg	clt	plg	plt	plg/ plt	t	Structure	Sculpture	References
<i>Cicercula</i>	<i>L. annuus</i>	M 36.68 σ ± 1.62 var. 11–13	33.09 ± 1.46 10–13	1.11 spheroidal	$\cong 1/1$	20.30 ± 1.48 16–21	1.86 ± 0.57 1–1	7.02 ± 0.50 5–7	9.05 ± 0.70 7–9	0.78	Non-measurable	Tectate infrastructurae	Mesocolpium distinct reticulate, reticules big apocolpium slightly reticulate	(Günes and Cırpici 2010)
	<i>L. hierosolymitanus</i>	M 31.20 σ 1.47 var. 11–13	29.07 1.16 10–12	1.07 spheroidal	$\cong 1/2$	30.27 1.53 20–24	4.87 0.70 3–4	12.32 1.01 7–10	13.22 1.016 8–11	0.93	Non-measurable	Tectate infrastructurae	Mesocolpium distinct reticulate, reticules big, apocolpium slightly reticulate	
	<i>L. cassius</i>	M 44.77 σ ± 2.10 var. 15–18	30.11 ± 1.95 10–13	1.48 prolate	$\cong 1/1$	43.37 ± 1.92 30–35	5.85 ± 1.21 3–6	12.71 ± 1.04 8–10	15.65 ± 1.17 10–13	0.81	Non-measurable	Tectate infrastructurae	Mesocolpium reticulate, reticules big, apocolpium almost psilate	
<i>L. gorgoni</i>	<i>L. gorgoni</i> var. <i>pilosus</i>	M 41.22 σ ± 1.59 var. 13–16	36.08 ± 1.48 11–14	1.14 subprolate	$\cong 1/2$	34.27 ± 1.31 27–32	2.74 ± 0.95 1–5	9.79 ± 0.90 7–10	11.44 ± 0.96 8–12	0.86	± 14.50	Tectate infrastructurae	Reticulate, distinct, big and irregular	(Günes and Cırpici 2010)
	<i>L. gorgoni</i> var. <i>gorgoni</i>	M 43.89 σ ± 1.44 var. 16–18	33.90 ± 1.37 12–14	1.30 subprolate	$\cong 2/1$	39.03 ± 1.99 30–37	3.83 ± 0.67 2–4	10.12 ± 0.74 8–10	12.18 ± 0.66 10–12	0.83	± 15.39	Tectate infrastructurae	Mesocolpium distinct reticulate-granulate apocolpium slightly reticulate	
	<i>L. pseudo-cicera</i>	M 42.43 σ ± 31.83 var. 15–18	34.37 ± 1.82 12–14	1.23 subprolate	$\cong 1/2$	36.59 ± 1.58 30–34	4.54 ± 0.93 3–5	8.60 ± 1.05 6–9	12.75 ± 1.11 9–13	0.67	Non-measurable	Tectate infrastructurae	Mesocolpium reticulate-granulate, apocolpium psilate	
<i>L. cicera</i>	<i>L. cicera</i>	M 41.71 σ ± 1.35 var. 13–15	31.58 ± 0.97 10–15	1.32 subprolate	$\cong 2/1$	31.39 ± 1.63 24–30	4.03 ± 0.73 2–5	4.38 ± 0.71 3–5	8.12 ± 0.94 5–9	0.54	± 17.11	Tectate infrastructurae	Reticulate, distinct, big and irregular	(Günes and Cırpici 2010)
	<i>L. sativus</i>	M 35.01 σ ± 1.30 var. 13–14	29.90 ± 1.30 11–12	1.17 subprolate	$\cong 1/2$	29.42 ± 1.29 24–30	3.24 ± 0.957 2–4	6.98 ± 0.67 5–7	10.81 ± 0.83 8–11	0.65	± 11.97	Tectate infrastructurae	Mesocolpium distinct reticulate-granulate, apocolpium slightly perforate	
	<i>L. blepharicarpus</i>	M 41.65 σ ± 1.51 var. 15–17	36.56 ± 1.59 13–15	1.15 subprolate	$\cong 3/1$	34.02 ± 0.98 28–31	3.24 ± 0.77 2–4	9.51 ± 0.84 7–10	13.36 ± 1.02 10–13	0.71	± 21.09	Tectate infrastructurae	Mesocolpium distinct reticulate-granulate apocolpium slightly perforate	
<i>L. stenophyllus</i>	<i>L. stenophyllus</i>	M 47.74 σ ± 1.78 var. 17–20	37.64 ± 1.49 13–15	1.27 subprolate	$\cong 2/1$	38.05 ± 1.56 30–35	4.93 ± 1.01 3–6	10.40 ± 0.87 8–10	11.72 ± 0.77 9–12	0.89	Non-measurable	Tectate infrastructurae	Mesocolpium reticulate-granulate, apocolpium slightly reticulate-granulate	
	<i>L. belinensis</i>	M 45.24 σ ± 2.44 var. 15–19	36.17 ± 2.38 10–15	1.25 subprolate	$\cong 2/1$	28.70 ± 1.09 24–27	1.85 ± 0.73 1–2	10.68 ± 0.79 8–10	13.25 ± 1.51 8–14	0.81	Non-measurable	Tectate infrastructurae	Mesocolpium reticulate, apocolpium slightly perforate	
	<i>L. phaselitanus</i>	M 37.05 σ ± 1.27 var. 13–15	29.89 ± 1.26 11–12	1.24 subprolate	$\cong 2/1$	29.42 ± 1.15 24–28	2.23 ± 0.61 1–3	8.28 ± 0.55 7–9	10.49 ± 0.64 8–10	0.79	± 21.66	Tectate infrastructurae	Mesocolpium slightly reticulate, apocolpium psilate	
<i>L. hirsutus</i>	<i>L. hirsutus</i>	M 38.98 σ ± 2.50 var. 13–14	32.78 ± 1.23 10–11	1.19 subprolate	$\cong 1/1$	27.88 ± 1.21 22–26	3.71 ± 0.84 2–4	8.29 ± 0.61 6–8	10.70 ± 0.66 8–10	0.76	Non-measurable	Tectate infrastructurae	Reticulate, slightly distinct, regular and small	(Günes and Cırpici 2010)

Table 2 continued

Sections	Taxa	<i>P</i>	<i>E</i>	<i>P/E</i>	<i>Ex/int</i>	<i>clg</i>	<i>clt</i>	<i>plg</i>	<i>plt</i>	<i>plg/plt</i>	<i>t</i>	Structure	Sculpture	References
<i>M</i> <i>σ</i> var.	<i>L. chrysanthus</i>	44.20	34.43	1.28	subprolate	30.48	2.12	8.16	9.92	0.82	Non-measurable	Tectate infrastructurae	Mesocolpium reticulate, apocolpium psilate	
		±2.84	±3.06			±1.91	±0.85	±1.13	±1.29					
		15–19	11–15			25–30	1–3	5–9	7–11					
<i>M</i> <i>σ</i> var.	<i>L. chloranthus</i>	41.03	31.69	1.30	subprolate	35.32	5.22	10.01	12.43	0.81	Non-measurable	Tectate infrastructurae	Mesocolpium distinct reticulate, reticules big and irregular, apocolpium slightly perforate	
		±0.65	±1.33			±1.43	±1.23	±0.27	±1.17					
		15–17	11–13			29–34	3–6	8–10	9–12					
<i>M</i> <i>σ</i> var.	<i>L. trachycarpus</i>	43.78	32.86	1.33	subprolate to prolate	29.71	2.92	10.44	12.84	0.81	Non-measurable	Tectate infrastructurae	Mesocolpium slightly reticulate, apocolpium psilate	
		±1.67	±1.54			±1.24	±0.61	±0.77	±0.78					
		15–18	11–14			24–28	2–4	8–10	10–13					

Marks (except variations) are in micrometres (μm). Variation numbers are bar numbers in LM

M arithmetic mean, *σ* standard deviation, *var* variations, *P* polar diameter, *E* equatorial diameter, *P/E* pollen shape, *Ex/int* the ratio of exine to intine thickness, *clg* colpus length, *clt* colpus width, *plg* porus length regarding the poles, *plt* porus width regarding the equatorial diameter, *plg/plt* porus shape, *t* one edge of the polar triangle, *structure* exine, *sculpture* ornamentation

3.69 μm; endoapertures-pori: large, borders distinct, protruding, lalongate, with an annulus (thickness sexine) and costae (thickness nexine) non-measurable, *plg*: 11.15 μm, *plt*: 13.95 μm and *plg/plt*: 0.80.

Outlines: equatorial view rectangular-obtuse-convex; polar view circular to triangular-obtuse-convex.

Ornamentation: reticulate, reticules big, different in size and shape, decreasing towards the apocolpium and colpus area psilate. The apocolpium is perforate.

Ex/int: $\cong 1/2$.

Exine: $\cong 1.14$ μm.

L. saxatilis (Table 2; Figs. 1e, f, 2g–i)

Pollen type: 3-zonocolporate.

Pollen shape: subprolate *P/E*: 1.22.

Dimensions: medium size ($P \times E = 37.24 \times 30.41$ μm).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: not long, borders not distinct, *clg*: 25.35 μm, *clt*: non-measurable, colpus and porus area granulate; endoapertures-pori: large, borders distinct, protruding, lalongate, with an annulus (thickness sexine) and costae (thickness nexine) non-measurable, *plg*: 7.75 μm, *plt*: 12.12 μm and *plg/plt*: 0.64.

Outlines: equatorial view elliptical-obtuse-convex; polar view circular to triangular.

Ornamentation: distinct reticulate-granulate, reticules different in size and shape, decreasing towards the apocolpium. The colpus area and porus area granulate, the apocolpium are almost psilate to perforate.

Ex/int: $\cong 2/1$.

Exine: $\cong 2.28$ μm.

L. vinealis (Table 2; Figs. 1g, h, 2k–m)

Pollen type: 3-zonocolporate.

Pollen shape: subprolate *P/E*: 1.25.

Dimensions: medium size ($P \times E = 36.49 \times 29.25$ μm).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: long, straight, nearly reaching the poles, wide, deep, with acute and obtuse ends, the borders little distinct, *clg*: 31.08 μm, *clt*: 5.68 μm; endoapertures-pori: large, borders distinct, lalongate, with an annulus (thickness sexine) and costae (thickness nexine) 2.28 μm, *plg*: 7.68 μm, *plt*: 12.97 μm and *plg/plt*: 0.59.

Outlines: equatorial view rectangular-obtuse-convex; polar view circular to triangular.

Ornamentation: reticulate, reticules big and distinct, different in size and shape, decreasing towards the apocolpium. The colpus-porus area and apocolpium are psilate.

Ex/int: 1/1.

Exine: $\cong 1.14$ μm.

L. inconspicuus var. *inconspicuus* (Table 2; Figs. 3a, b, 4a–c)

Fig. 1 Pollen grains of examined taxa in LM. **a, b** *Lathyrus rotundifolius* subsp. *miniatus*, **c, d** *L. grandiflorus*, **e, f** *L. saxatilis*, **g, h** *L. vinealis*, **a, c, e, g** polar view, **b, d, f, h** equatorial view

Pollen type: 3-zonocolporate.

Pollen shape: spheroidal P/E : 1.03.

Dimensions: medium size ($P \times E = 31.62 \times 30.58 \mu\text{m}$).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: short, straight, wide, shallow, with obtuse ends, the borders not distinct, same width on pori, clg: $18.08 \mu\text{m}$, clt: $2.37 \mu\text{m}$; endoapertures-pori: small, borders distinct, protruding, lalongate, with an annulus (thickness sexine) and costae (thickness nexine) non-measurable, plg: $7.39 \mu\text{m}$, plt: $8.78 \mu\text{m}$ and plg/plt: 0.84.

Outlines: equatorial view rectangular-obtuse-emarginate; polar view quinquangular-obtuse-concave.

Ornamentation: mesocolpium area is concave, aperture area and concavity reticulate-granulate in mesocolpium, reticules small, different in size. Outside these areas and the apocolpium are psilate, with polar triangular perforate.

Ex/int: $\cong 1/1$.

Exine: $\cong 1.14 \mu\text{m}$.

L. inconspicuus var. *stenophyllus* (Table 2; Figs. 3c, d, 4d–f)

Pollen type: 3-zonocolporate.

Pollen shape: spheroidal P/E : 1.03.

Dimensions: medium size ($P \times E = 31.98 \times 30.99 \mu\text{m}$).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: short, straight, wide, shallow, with obtuse ends, the borders not distinct, same width on pori, clg: $18.56 \mu\text{m}$, clt: $2.85 \mu\text{m}$; endoapertures-pori: small, borders distinct, protruding, lalongate, with an annulus (thickness sexine) and costae (thickness nexine) non-measurable, plg: $7.18 \mu\text{m}$, plt: $8.76 \mu\text{m}$ and plg/plt: 0.82.

Outlines: equatorial view rectangular-obtuse-emarginate; polar view quinquangular-obtuse-concave.

Ornamentation: mesocolpium areas are concave, aperture area and concavity reticulate-granulate in mesocolpium, reticules small, different in size. Outside these areas and the apocolpium are psilate, with polar triangular perforate.

Ex/int: $\cong 1/1$.

Exine: $\cong 1.14 \mu\text{m}$.

L. tauricola (Table 2; Figs. 3e, f, 4g–i)

Pollen type: 3-zonocolporate.

Pollen shape: spheroidal P/E : 0.99.

Dimensions: medium size ($P \times E = 30.94 \times 31.20 \mu\text{m}$).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: short, shallow, with obtuse and acute ends, the borders slightly distinct, broader on pori, clg: $16.76 \mu\text{m}$, clt: $4.17 \mu\text{m}$; endoapertures-pori: middle in size, protruding, borders distinct, lalongate, with an annulus (thickness sexine) and costae (thickness nexine) $3.20 \mu\text{m}$, plg: $6.59 \mu\text{m}$, plt: $8.48 \mu\text{m}$ and plg/plt: 0.78.

Outlines: equatorial view rectangular-obtuse-emarginate; polar view triangular-obtuse-convex.

Ornamentation: mesocolpium areas are concave, aperture area and concavity reticulate-granulate in mesocolpium, reticules small, different in size. Outside these areas and the apocolpium are psilate, with polar triangular perforate.

Ex/int: $\cong 2/1$.

Exine: $\cong 1.14 \mu\text{m}$.

L. woronowii (Table 2; Figs. 3g,h, 4k–m)

Pollen type: 3-zonocolporate.

Pollen shape: prolate P/E : 1.36.

Dimensions: medium size ($P \times E = 35.78 \times 26.31 \mu\text{m}$).

Fig. 2 Pollen grains of examined taxa in SEM. **a, b, c** *Lathyrus rotundifolius* subsp. *miniatus* **d, e, f** *L. grandiflorus*, **g, h, i** *L. saxatilis*, **k, l, m** *L. vinealis*, **a, d, g, k** polar view, **b, e, h, l** equatorial view, **c, f, i, m** ornamentation

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: long, straight, deep, with acute ends, the borders distinct, clg: 26.93 μm , clt: 4.06 μm ; endoapertures-pori: large, borders distinct, lalongate, with an annulus (thickness sexine) and costae (thickness nexine) 1.14 μm , plg: 9.05 μm , plt: 11.42 μm and plg/plt: 0.79.

Outlines: equatorial view rectangular-obtuse-convex; polar view circular to triangular.

Ornamentation: reticulate, reticules big and irregular different in size and shape in the mesocolpium, decreasing towards the apocolpium. Colpus area is psilate. Polar areas are very slightly reticulate.

Ex/int: $\cong 1/1$.

Exine: $\cong 1.14 \mu\text{m}$.

L. hierosolymitanus (Table 2; Figs. 5a, b, 6a–c)

Pollen type: 3-zonocolporate.

Pollen shape: spheroidal P/E : 1.07.

Dimensions: medium size ($P \times E = 31.20 \times 29.07 \mu\text{m}$).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: very long, straight, nearly reaching the poles, shallow and wide, with obtuse ends, the borders distinct, widening on pori in mesocolpium, clg: 30.27 μm , clt: 4.87 μm ; endoapertures-pori: large, borders distinct, slightly lalongate, with an annulus (thickness sexine) and costae (thickness nexine) thin than 1.14 μm , plg: 12.32 μm , plt: 13.22 μm and plg/plt: 0.93.

Outlines: equatorial view elliptic-obtuse-convex; polar view circular to triangular-obtuse-convex.

Ornamentation: reticulate, reticules different in size and shape in the mesocolpium, decreasing towards the apocolpium. The colpus area is psilate, the apocolpium is slightly reticulate.

Ex/int: 1/2.

Exine: $\cong 1.14 \mu\text{m}$.

Fig. 3 Pollen grains of examined taxa in LM. **a, b** *Lathyrus inconspicuus* var. *inconspicuus*, **c, d** *L. inconspicuus* var. *stenophyllus*, **e, f** *L. tauricola*, **g, h** *L. woronowii*, **a, c, e, g** polar view, **b, d, f, h** equatorial view

L. cassius (Table 2; Figs. 5c, d, 6d–f)

Pollen type: 3-zonocolporate.

Pollen shape: prolate $P/E = 1.48$.

Dimensions: medium size ($P \times E = 44.77 \times 30.11 \mu\text{m}$).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: long, straight, deep, nearly reaching the poles, borders distinct, broader on pori, with acute ends, clg: $43.37 \mu\text{m}$, clt: $5.85 \mu\text{m}$; endoapertures-pori: large, lalongate, borders distinct, with an thin annulus (thickness sexine) and costae (thickness nexine) $2.28 \mu\text{m}$, plg: $12.71 \mu\text{m}$, plt: $15.65 \mu\text{m}$ and $\text{plg/plt} = 0.81$.

Outlines: equatorial view rectangular-obtuse-convex; polar view triangular to circular.

Ornamentation: reticulate, reticules different in size and shape in the mesocolpium, decreasing towards the apocolpium. The colpus area is psilate. The polar area has small scattered perforations or psilate.

Ex/int: 1/1.

Exine: $\cong 1.14 \mu\text{m}$.

L. gorgoni var. *gorgoni* (Table 2; Figs. 5e, f, 6g–i)

Pollen type: 3-zonocolporate.

Pollen shape: subprolate $P/E: 1.30$.

Dimensions: medium size ($P \times E = 43.89 \times 33.90 \mu\text{m}$).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: long, straight, deep, shallow and wide, nearly reaching the poles, borders distinct, with acute ends, clg: $39.03 \mu\text{m}$, clt: $3.83 \mu\text{m}$; endoapertures-pori: large, lalongate, borders distinct, protruding, with an annulus (thickness sexine) and costae (thickness nexine) $2.85 \mu\text{m}$, plg: $10.12 \mu\text{m}$, plt: $12.18 \mu\text{m}$ and $\text{plg/plt} = 0.83$.

Outlines: equatorial view elliptic to rectangular-obtuse-convex; polar view circular-obtuse-convex.

Ornamentation: reticulate–granulate, reticules big and irregular, different in size and shape in the mesocolpium. The aperture area is psilate. The apocolpium is slightly reticulate.

Ex/int: $\cong 2/1$.

Exine: $\cong 2.28 \mu\text{m}$.

L. pseudo-cicera (Table 2; Figs. 5g, h, 6k–m)

Pollen type: 3-zonocolporate.

Pollen shape: subprolate $P/E: 1.23$.

Dimensions: medium size ($P \times E = 42.43 \times 34.37 \mu\text{m}$).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: long, straight, deep, borders not distinct, nearly reaching the poles, with acute ends, clg: $36.59 \mu\text{m}$, clt: $4.54 \mu\text{m}$; endoapertures-pori: large, lalongate, borders distinct, with an annulus (thickness exine) and costae (thickness nexine) $2.85 \mu\text{m}$, plg: $8.60 \mu\text{m}$, plt: $12.75 \mu\text{m}$ and $\text{plg/plt} = 0.67$.

Outlines: equatorial view rectangular-obtuse-convex; polar view circular to triangular-obtuse-convex.

Ornamentation: reticulate–granulate (columellae), reticules different in size and shape in the mesocolpium, decreasing towards the apocolpium. The aperture area is reticulate, the polar area is psilate.

Ex/int: $\cong 1/2$.

Exine: $\cong 1.14 \mu\text{m}$.

L. sativus (Table 2; Figs. 7a, b, 8a–c)

Pollen type: 3-zonocolporate.

Pollen shape: subprolate $P/E: 1.17$.

Dimensions: medium size ($P \times E = 35.01 \times 29.90 \mu\text{m}$).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane);

Fig. 4 Pollen grains of examined taxa in SEM. **a, b, c** *Lathyrus inconspicuus* var. *inconspicuus*, **d, e, f** *L. inconspicuus* var. *stenophyllus*, **g, h, i** *L. tauricola*, **k, l, m** *L. woronowii*, **a, d, g, k** polar view, **b, e, h, l** equatorial view, **c, f, i, m** ornamentation

ectoapertures-colpi: long, straight, deep, nearly reaching the poles, borders distinct, with acute ends, widened on pori, clg: 29.42 μm , clt: 3.24 μm ; endoapertures-pori: large, lalongate, borders distinct, with an annulus (thickness sexine) and costae (thickness nexine) 2.28 μm , plg: 6.98 μm , plt: 10.81 μm and plg/plt = 0.65.

Outlines: equatorial view elliptical-obtuse-convex; polar view circular to slightly triangular-obtuse-convex.

Ornamentation: reticulate-granulate, reticules are medium in size. The aperture area is psilate, the apocolpium is slightly reticulate-perforate.

Ex/int: $\cong 1/2$.

Exine: $\cong 1.14 \mu\text{m}$.

L. blepharicarpus (Table 2; Figs. 7c, d, 8d–f)

Pollen type: 3-zonocolporate.

Pollen shape: subprolate *P/E*: 1.15.

Dimensions: medium size ($P \times E = 41.65 \times 36.56 \mu\text{m}$).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: long, straight, shallow to deep, borders less

distinct, with acute ends, clg: 34.02 μm , clt: 3.24 μm ; endoapertures-pori: large, lalongate, borders less distinct, protruding in mesocolpium, with an annulus (thickness sexine) and costae (thickness nexine) 2.85 μm , plg: 9.51 μm , plt: 13.36 μm and plg/plt = 0.71.

Outlines: equatorial view elliptic-obtuse-convex; polar view circular to slightly triangular-obtuse-convex.

Ornamentation: reticulate-granulate, reticules big and irregular in size and shape. In the mesocolpium, the aperture area is slightly reticulate and not granulate, and the apocolpium is perforate.

Ex/int: $\cong 3/1$.

Exine: $\cong 1.14 \mu\text{m}$.

L. stenophyllus (Table 2; Figs. 7e, f, 8g–i).

Pollen type: 3-zonocolporate.

Pollen shape: subprolate *P/E*: 1.27.

Dimensions: medium size ($P \times E = 47.74 \times 37.64 \mu\text{m}$).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: long, nearly reaching the poles, borders less

Fig. 5 Pollen grains of examined taxa in LM. **a, b** *Lathyrus hierosolymitanus*, **c, d** *L. cassius*, **e, f** *L. gorgoni* var. *gorgoni*, **g, h** *L. pseudo-cicera*, **a, c, e, g** polar view **b, d, f, h** equatorial view

distinct, wide, deep, with acute ends, clg: 38.05 µm, clt: 4.93 µm; endoapertures-pori: large, lalongate, borders distinct, with an thin annulus (thickness sexine) and costae (thickness nexine) 2.5 µm, plg: 10.40 µm, plt: 11.72 µm and plg/plt = 0.89.

Outlines: equatorial view rectangular-obtuse-convex; polar view circular to triangular-obtuse-convex.

Ornamentation: Reticulate-slightly granulate, reticules big and irregular in size and shape. In the mesocolpium, the aperture area is psilate, and the apocolpium is slightly reticulate-granulate.

Ex/int: $\cong 2/1$.

Exine: $\cong 2.28$ µm.

L. belinensis (Table 2; Figs. 7g, h, 8k–m)

Pollen type: 3-zonocolporate.

Pollen shape: subprolate P/E : 1.25.

Dimensions: medium size ($P \times E = 45.24 \times 36.17$ µm).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: long, straight, borders distinct, narrow, deep, with acute ends, clg: 28.70 µm, clt: 1.85 µm; endoapertures-pori: large, lalongate, borders distinct, with an annulus (thickness sexine) and costae (thickness nexine) 2.19 µm, plg: 10.68 µm, plt: 13.25 µm and plg/plt = 0.81.

Outlines: equatorial view rectangular-obtuse-convex; polar view circular to quiguangular-obtuse-convex.

Ornamentation: reticulate, reticules big and different in size and shape, distinct to less distinct in the mesocolpium. The aperture areas are psilate, and the apocolpium is slightly perforate.

Ex/int: 2/1.

Exine: $\cong 1.14$ µm.

L. phaselitanus (Table 2; Figs. 9a, b, 10a–c)

Pollen type: 3-zonocolporate.

Pollen shape: subprolate P/E : 1.24

Dimensions: medium size ($P \times E = 37.05 \times 28.89$ µm).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: long, straight, borders distinct, shallow to deep, broader on the pori, with acute ends, clg: 29.42 µm, clt: 2.23 µm; endoapertures-pori: not large, lalongate, borders distinct, with an thin annulus (thickness sexine) and costae (thickness nexine) 2.85 µm, plg: 8.28 µm, plt: 10.49 µm and plg/plt = 0.79.

Outlines: equatorial view rectangular-obtuse-convex; polar view triangular.

Ornamentation: slightly reticulate to psilate, reticules are different in size in the mesocolpium. The aperture area and apocolpium are psilate.

Ex/int: 2/1.

Exine: $\cong 1.14$ µm.

L. chrysanthus (Table 2; Figs. 9c, d, 10d–f)

Pollen type: 3-zonocolporate.

Pollen shape: subprolate P/E : 1.28.

Dimensions: medium size ($P \times E = 44.20 \times 34.43$ µm).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: not long, straight, borders distinct, deep, same width in the mesocolpium (on pori), with acute ends, clg: 30.48 µm, clt: 2.12 µm; endoapertures-pori: large, lalongate, borders distinct, protruding or not in mesocolpium, with an annulus (thickness sexine) and heavy thick costae (thickness nexine) 4.10 µm, plg: 8.16 µm, plt: 9.92 µm and plg/plt = 0.82.

Outlines: equatorial view rectangular-obtuse-convex; polar view triangular to circular.

Fig. 6 Pollen grains of examined taxa in SEM. **a, b, c** *Lathyrus hierosolymitanus*, **d, e, f** *L. cassius*, **g, h, i** *L. gorgoni* var. *gorgoni*, **k, l, m** *L. pseudo-cicera*, **a, d, g, k** polar view, **b, e, h, l** equatorial view, **c, f, i, m** ornamentation

Ornamentation: reticulate; reticules are different in size and shape in the mesocolpium. The aperture area and apocolpium are psilate.

Ex/int: $\cong 2/1$.

Exine: $\cong 0.57 \mu\text{m}$.

L. chloranthus (Table 2; Figs. 9e, f, 10g–i)

Pollen type: 3-zonocolporate.

Pollen shape: subprolate P/E : 1.26.

Dimensions: medium size ($P \times E = 39.68 \times 31.56 \mu\text{m}$).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: long, straight, wide, deep, nearly reaching the poles, borders not distinct, same width on pori, with acute ends, clg: $35.98 \mu\text{m}$, clt: $6.02 \mu\text{m}$; endoapertures-pori: large, lalongate, borders distinct, with an annulus (thickness sexine) and costae (thickness nexine) $1.71 \mu\text{m}$, plg: $9.78 \mu\text{m}$, plt: $11.13 \mu\text{m}$ and plg/plt = 0.88.

Outlines: equatorial view rectangular-obtuse-convex; polar view triangular to circular.

Ornamentation: distinct reticulate, reticules big, different in size and shape in the mesocolpium. The aperture area is psilate, and the apocolpium is slightly perforate.

Ex/int: $\cong 1/2$.

Exine: $\cong 0.57 \mu\text{m}$.

L. trachycarpus (Table 2; Figs. 9g, h, 10k–m)

Pollen type: 3-zonocolporate.

Pollen shape: subprolate to prolate P/E : 1.33.

Dimensions: medium size ($P \times E = 43.78 \times 32.86 \mu\text{m}$).

Apertures: apertures with an intine protrusion (thickening of the middle of the aperture membrane); ectoapertures-colpi: not long, not straight, borders distinct, deep, same width on pori, with acute ends, clg: $29.71 \mu\text{m}$, clt: $2.92 \mu\text{m}$; endoapertures-pori: large, lalongate, borders distinct, with a thick annulus (thickness sexine) and costae

Fig. 7 Pollen grains of examined taxa in LM. **a, b** *Lathyrus sativus*, **c, d** *L. blepharicarpus*, **e, f** *L. stenophyllus*, **g, h** *L. belinensis*, **a, c, e, g** polar view, **b, d, f, h** equatorial view

(thickness nexine) 2.85 µm, plg: 10.44 µm, plt: 12.84 µm and plg/plt = 0.81.

Outlines: equatorial view rectangular-obtuse-convex; polar view triangular.

Ornamentation: slightly reticulate, reticules are different in size and shape in the mesocolpium. The aperture area and apocolpium are psilate.

Ex/int: $\cong 1/2$.

Exine: $\cong 0.57$ µm.

The pollen grains of the analysed taxa were divided into groups according to their equatorial view and shape as follows:

According to the equatorial view:

Section *Lathyrus*

1. Rectangular: *L. rotundifolius* subsp. *miniatus*, *L. grandiflorus*, *L. undulatus*, *L. sylvestris*
2. Elliptical: *L. tuberosus*

Section *Orobastrum*

1. Elliptical: *L. saxatilis*, *L. sphaericus*, *L. setifolius*
2. Rectangular: *L. vinealis*, *L. woronowii*
3. Rectangular-emarginate: *L. inconspicuus* var. *inconspicuus*, *L. inconspicuus* var. *stenophyllus*, *L. tauricola*.

Section *Cicerula*

1. Elliptical: *L. annuus*, *L. hierosolymitanus*, *L. sativus*, *L. blepharicarpus*,
2. Elliptical to rectangular: *L. gorgoni* var. *gorgoni*, *L. gorgoni* var. *pilosus*, *L. cicera*, *L. hirsutus*
3. Rectangular: *L. cassius*, *L. pseudo-cicera*, *L. stenophyllus*, *L. belinensis*, *L. phaselitanus*, *L. chrysanthus*, *L. chloranthus*, *L. trachycarpus*,

According to pollen shape:

Section *Lathyrus*

1. Spheroidal: *L. tuberosus*
2. Subprolate: *L. rotundifolius* subsp. *miniatus*, *L. undulatus*, *L. sylvestris*
3. Prolate: *L. grandiflorus*

Section *Orobastrum*

1. Spheroidal: *L. inconspicuus* var. *inconspicuus*, *L. inconspicuus* var. *stenophyllus*, *L. tauricola*, *L. sphaericus*, *L. setifolius*
2. Subprolate: *L. saxatilis*, *L. vinealis*
3. Prolate: *L. woronowii*

Section *Cicerula*

1. Spheroidal: *L. annuus*, *L. hierosolymitanus*
2. Subprolate: *L. gorgoni* var. *pilosus*, *L. gorgoni* var. *gorgoni*, *L. pseudo-cicera*, *L. cicera*, *L. sativus*, *L. blepharicarpus*, *L. stenophyllus*, *L. belinensis*, *L. phaselitanus*, *L. hirsutus*, *L. chrysanthus*, *L. chloranthus*
3. Subprolate to Prolate: *L. trachycarpus*
4. Prolate: *L. cassius*

The aperture system: intine protrusion and distinct annulus above the apertures. Ectoapertures-colpi: usually long, straight, borders distinct or not, shallow or deep, narrow or wide, usually with acute ends. Endoapertures-

Fig. 8 Pollen grains of examined taxa in SEM. **a, b, c** *Lathyrus sativus*, **d, e, f** *L. blepharicarpus*, **g, h, i** *L. stenophyllus*, **k, l, m** *L. belinensis*, **a, d, g, k** polar view, **b, e, h, l** equatorial view, **c, f, i, m** ornamentation

pori: large, lalongate, borders distinct, protruding in the mesocolpium or not.

Exine; tectate-infrastructure and exine thickness ranged between 0.57 and 2.28 μm . The thickest exine was observed in *L. saxatilis*, *L. gorgoni* var. *gorgoni*, and *L. stenophyllus*, and the thinnest exine was observed in *L. chrysanthus*, *L. chloranthus*, and *L. trachycarpus*.

The ornamentation was reticulate, reticulate-granulate, or slightly reticulate in the mesocolpium. The apocolpium and the aperture area were usually psilate.

Discussion

With this study, the pollen morphology of the 63 taxa that have spread in Turkey up to the present day has been determined (Aytug et al. 1971; Günes and Cırpıcı 1998, 2010; Günes and Aytug 2010; Güneş 2011a, b; Çildır 2011; Kahraman et al. 2012). This number comprises about 85 % of all species of *Lathyrus* in Turkey. Of the 63 taxa,

the pollen morphologies have been determined, with the largest pollen originating from *L. clymenum* ($P = 52.42$; $E = 35.82 \mu\text{m}$, prolate) and *L. ochrus* ($P = 52.66$; $E = 33.02 \mu\text{m}$, prolate), and the smallest pollen found in the *L. tauricola* ($P = 30.94$; $E = 31.20 \mu\text{m}$, spheroidal), *L. inconspicuus* var. *inconspicuus* ($P = 31.62$; $E = 30.58 \mu\text{m}$, spheroidal) and *L. inconspicuus* var. *stenophyllus* ($P = 31.98$; $E = 30.99 \mu\text{m}$, spheroidal) taxa. This shows that the largest pollen samples were observed in the *Clymenum* section, and the smallest pollen types were observed in the *Orobastrum* sections. Pollen of the monotypic species of *L. nissolia* in the *Nissolia* section ($P = 32.79$; $E = 24.75 \mu\text{m}$, subprolate to prolate) was small and similar to those in the *Orobastrum* section. The smallest pollen in the *Pratensis* section belongs to *L. pratensis* ($P = 36.83$; $E = 29.75 \mu\text{m}$, subprolate), and the largest pollen belongs to the *L. czechottianus* ($P = 43.08$; $E = 31.20 \mu\text{m}$, prolate) taxon (Günes and Aytug 2010), whereas the smallest pollen in the *Platystylis* section belongs to *L. elongates* ($P = 36.97$; $E = 38.64 \mu\text{m}$,

Fig. 9 Pollen grains of examined taxa in LM. **a, b** *Lathyrus phaselitanus*, **c, d** *L. chrysanthus*, **e, f** *L. chloranthus*, **g, h** *L. trachycarpus*, **a, c, e, g** polar view, **b, d, f, h** equatorial view

spheroidal), and the largest pollen belongs to the *L. cyanus* var. *cyaneus* ($P = 46.33$; $E = 32.86$ µm, prolate) taxon (Güneş 2011a). The smallest pollen in the *Lathyrus* section was from the *L. tuberosus* ($P = 34.69$; $E = 31.72$ µm, spheroidal) (Güneş 2011b), whereas the largest pollen was from the *L. grandiflorus* ($P = 50.60$; $E = 36.40$ µm, prolate) taxon; the smallest pollen in section *Orobastrum* was from *L. tauricola* ($P = 30.94$; $E = 31.20$ µm, spheroidal), whereas the largest pollen was from *L. saxatilis* ($P = 37.24$; $E = 30.41$ µm, subprolate); the smallest pollen in section *Cicerula* was from *L. hierosolymitanus* ($P = 31.20$; $E = 29.07$ µm, spheroidal),

while the largest pollen was from *L. stenophyllus* ($P = 47.74$; $E = 37.64$ µm, subprolate) taxon.

Moore et al. (1991) determined the *Lathyrus* pollen grains as the *Vicia cracca* type (e.g., *L. montanus*), the *Vicia sylvatica* type (e.g., *L. sylvestris*), or the *Lathyrus* type (e.g., *L. pratensis*). Tosheva and Tonkov, additionally, found the *Lathyrus filiformis* type, which is a fourth type in section *Platystylis*, and *L. inconspicuus* var. *inconspicuus*, *L. inconspicuus* var. *stenophyllus*, and *L. tauricola* taxa. Outside of Turkey, the *Lathyrus* taxa has been rarely analysed until now (Gapotchka and Chamara 1972; Gapotchka 1974; Faegri and Iversen 1989; Tosheva et al. 2004; Tosheva and Tonkov 2005, 2007). The pollen of *L. grandiflorus* ($P \times E = 47.4$ (58.6) 66.4×39.5 (46.3) 53.7 µm, subprolate) was identified as the largest pollen by Tosheva et al. (2004). The results of the current study suggest that the pollen here is greater and the shape is different when compared with their values (Table 2).

While the pollen morphological properties of all taxa in sections *Platystylis*, *Pratensis*, *Lathyrus*, *Orobastrum* and *Nissolia* that are found naturally in Turkey have been determined, the pollen morphological properties of a total of 11 taxa in the *Orobus*, *Orobon*, *Cicerula*, *Clymenum*, and *Aphaca* sections have not yet been determined. When the *Lathyrus* pollen are evaluated in general, the pollen are mostly of the type *Vicia cracca*, *V. sylvatica*, *Lathyrus*, and *L. filiformis*, with *Lathyrus* and *V. sylvatica* types observed the most. Seventeen taxa have spheroidal pollen, whereas 35 taxa have subprolate and 11 taxa have prolate-shaped pollen. The colpi is generally long and flat, while the porus is large and lalongate. The equatorial view is generally elliptical to rectangular; the polar view is circular, triangular, and quinquangular (as *L. inconspicuus* var. *inconspicuus*, *L. inconspicuus* var. *stenophyllus*, *L. tauricola*). The structures are tectate infrastructure, sculpture (ornamentation); reticulate, reticulate-granulate or reticulate-perforate; and the size and arrangement of the reticules along the stem, as well as whether they are more distinct or not, differ with respect to the species.

When the pollen morphologies of *L. saxatilis*, *L. cassius*, *L. chrysanthus*, and *L. trachycarpus* taxa are examined, amorphous-shaped pollen with 3–4–5 pores and colpus with different shapes have been observed (within the preparations from the species collected from the other localities a total of 3–4 multi-porus and colpus types of pollen were observed). The ratio of the amorphous pollen is about 20 %. It is thought that there are various abnormalities in the pollen embryological developments of these species, and it has been observed in *L. grandiflorus*, *L. saxatilis*, *L. sativus*, *L. blepharicarpus*, and *L. belinensis* that the pollen germinated in the preparates. No remarkable distinctions were found when analysing the samples of the other taxa

Fig. 10 Pollen grains of examined taxa in SEM. **a, b, c** *Lathyrus phaselitanus*, **d, e, f** *L. chrysanthus*, **g, h, i** *L. chloranthus*, **k, l, m** *L. trachycarpus*, **a, d, g, k** polar view, **b, e, h, l** equatorial view, **c, f, i, m** ornamentation

collected from the different localities. Pollen characteristics are not affected by geographical changes (Aytug 1959).

When the results are compared with those obtained by Kahraman et al. (2012), it is seen that the pollen dimension findings for *L. chloranthus* ($P \times E = 46.82 \times 37.16 \mu\text{m}$) are larger than those in our study, whereas the colpus length (clg) of *L. inconspicuus* is longer ($27.78 \mu\text{m}$), the clg of *L. saxatilis* is longer, and the plg and plt values are smaller (Table 2).

Cronquist (1968) reported that pollen sculpture types have valid morphological features in taxonomy. Thus, the taxonomic value of these *Lathyrus* taxa, as well as their pollen morphology, could be a distinguishing criterion. In conclusion, the morphological structures of pollen seem to be useful for differentiating between taxa; thus, it is suggested that they could be of benefit in taxonomical studies.

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