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Pollen morphology of the genus *Lathyrus* L. (Fabaceae) with emphasis on its systematic implications

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Abstract

The pollen morphology of 21 taxa of the genus *Lathyrus*, representing 9 sections *Orobus*, *Lathyrostylis* (=*Platystylis*), *Lathyrus* (syn. *Cicercula*), *Orobon*, *Pratensis*, *Aphaca*, *Viciopsis*, *Linearicarpus* and *Nissolia* from Central Anatolia, Turkey was investigated using light microscopy (LM) and scanning electron microscopy (SEM). The pollen grains of the studied taxa are 3-zonocolporate, spheroidal to prolate and medium to large (P = 28.67-54.32 µm, E = 20.17-52.58 µm). Their outline in the equatorial view is quadratic-obtuse-emarginate in *L. tukhtensis*, *L. cilicicus* and *L. inconspicuus* var. *inconspicuus* or elliptical to rectangular-obtuse-convex in the other taxa, and in the polar view it is circular, triangular or quinquangular-obtuse-convex. The surface ornamentation of the mesocolpium varies from obscurely reticulate-perforate in *L. incurvus*, *L. brachypterus*, *L. armeus* and *L. hirsutus*; perforate in *L. tukhtensis* and *L. cilicicus*; reticulate-granulate in *L. cicera*; perforate-granulate in *L. inconspicuus* var. *inconspicuus* to finely reticulate-perforate in the rest of the taxa. The apocolpium and colpus area are psilate or perforate in all taxa except *L. chloranthus*, which exhibits the finely reticulate-perforate pattern. The findings of the study reveal that pollen morphological characters such as the surface sculpturing type, pollen size, shape and outline in equatorial view are mostly useful in distinguishing the studied taxa, but they do not provide strong evidence for the infrageneric delimitation of the genus.

Keywords: Pollen morphology, *Lathyrus*, Fabaceae, Central Anatolia, Turkey.

Introduction

Lathyrus L. is the largest genus in the economically important tribe Fabeae (syn. Vicieae) of the subfamily Papilionoideae (or Faboideae), with about 170 annual and perennial species in the world (Lewis et al., 2005; ILDIS, 2010). *Lathyrus* is an almost exclusively temperate genus and its species are distributed throughout the northern hemisphere, with a disjunction in South America (Kenicer, 2008). The eastern Mediterranean region is the main center of diversity for the genus, which is less diversified in North and South America (Kupicha, 1983; Simola, 1986). A few species also reach tropical and the highlands of East Africa (Senn, 1938; Davis, 1970; Kenicer et al., 2005). Endemic species are distributed in all continents, except Australia and Antarctica (Kupicha, 1981). Many species of *Lathyrus* are mesophytes with erect, climbing or sprawling habit and preferring open woodlands, forest margins, roadside verges, littoral, alpine and drought habitats (Kenicer et al., 2005). *Lathyrus* species are economically important plants, consisting of food and fodder crops, ornamentals, soil nitrifiers, dune stabilizers, significant agricultural weeds, and model organisms for genetic and ecological research (Chittenden, 1951; Kenicer et al., 2005). *L. cicera* L., *L. latifolius* L., *L. odoratus* L., *L. sativus* L. and *L. tuberosus* L. have commercial importance, especially for their ornamental value or as forages and feed. Moreover, *L. aphaca* L., *L. clymenum* L., *L. hirsutus* L. and *L. pratensis* L. are very well as weedy aliens and can also be found almost anywhere (Kenicer, 2008). Most researchers separate *Lathyrus* into 12 or 13 sections in the world (Czefranova, 1971; Kupicha, 1983; Asmussen and Liston, 1998; ILDIS, 2002; Leht, 2009). Kupicha's (1983) infrageneric classification of the genus is the most comprehensive of recent accounts. She classified it into 13 sections on the basis of morphological traits: *Orobus*, *Lathyrostylis*, *Lathyrus*, *Orobon*, *Pratensis*, *Aphaca*, *Clymenum*, *Orobastrum*, *Viciopsis*, *Linearicarpus*, *Nissolia*, *Neurolobus* and *Notolathyrus*. Since Kupicha's (1983) monograph, Doğan et al. (1992) performed a phenetic analysis of vegetative and floral characters of 54 *Lathyrus* species in Turkey. Their results showed that these species were clustered into 9 sections, and confirmed sections *Orobus*, *Lathyrostylis,* and *Clymenum* proposed by Kupicha (1983), however disagreed on the circumscription of the remaining sections. Davis (1970) also recognized 58 *Lathyrus* species from Turkey under 10 sections. Kupicha's (1983) classification system has been generally supported by many recent molecular phylogenetic studies (e.g. Croft et al., 1999; Kenicer et al., 2005). However, cpDNA (Croft et al., 1999) and AFLP analyses (Badr et al., 2002) of *Lathyrus* species propose that reclassification of some species to different sections may be required. In Turkey, the genus is

represented by 76 taxa (66 species) (Davis, 1970; Davis et al., 1988; Güneş and Özhatay, 2000; Genç and Şahin, 2011), belonging to eleven sections according to the infrageneric system of Kupicha (1983): *Orobus*, *Lathyrostylis* (=*Platystylis*), *Lathyrus* (syn. *Cicercula*), *Orobon*, *Pratensis*, *Aphaca*, *Clymenum*, *Orobastrum*, *Viciopsis*, *Linearicarpus* and *Nissolia*. Turkey is a major centre of diversity for the genus in Euroasia with a high number of species compared to neighbouring countries: 54 species in Flora Europaea (Tutin and Heywood, 1981), 50 in Flora of the USSR (Fedchenko, 1948), 25 in Flora Iranica (Rechinger, 1979), 18 in Flora of Iraq (Townsend and Guest, 1977) and 11 in Flora of Cyprus (Meikle, 1977). The pollen morphology of some taxa of *Lathyrus* has been previously studied (Faegri, 1956; Gapotchka and Chamara, 1972; Gapotchka, 1974; Clarke and Kupicha, 1976; Fergusson and Skvarla, 1981; Faegri and Iversen, 1989; Moore et al., 1991; Perveen and Qaiser, 1998; Halbritter, 2000; Mantar et al., 2001, 2003; Beug, 2004; Tosheva and Tonkov, 2005, 2007; Güneş and Aytuğ, 2010; Güneş and Çırpıcı, 2010; Güneş, 2011a, b). Moore et al. (1991) classified *Lathyrus* pollen grains as *Vicia cracca* type and *Lathyrus* type. In Bulgaria, Tosheva and Tonkov (2007) found a new pollen type, the *Lathyrus filiformis* type, indicated by *L. filiformis*, *L. pallescens* and *L. pancicii* from sect. *Lathyrostylis*. Since 2009, the second author has undertaken a revision study of *Lathyrus* in Central Anatolia and collected a large number of specimens during his extensive field studies (Çildir, 2011). The present study aims to provide a detailed account of the pollen morphology of 21 taxa of *Lathyrus*, belonging to 9 sections *Orobus*, *Lathyrostylis*, *Lathyrus*, *Orobon*, *Pratensis*, *Aphaca*, *Viciopsis*, *Linearicarpus* and *Nissolia* distributed in Central Anatolia, using LM and SEM, and to evaluate the usefulness of the palynological data in the classification within the genus.

Results

Pollen grains of 21 *Lathyrus* taxa, placed in 9 sections *Orobus*, *Lathyrostylis*, *Lathyrus*, *Orobon*, *Pratensis*, *Aphaca*, *Viciopsis*, *Linearicarpus* and *Nissolia* from Central Anatolia ,Turkey show variation in size, shape and exine ornamentation. The main pollen characters of the taxa are summarized in Table 2. SEM micrographs of representative pollen grains studied are illustrated in Figs. 1-5.

Pollen size and shape

The pollen grains of the taxa examined vary in size: polar axis (P) ranges from 28.67 µm, in *L. inconspicuus* var. *inconspicuus*, to 54.32 µm, in *L. tukhtensis* and equatorial axis (E) ranges from 20.17 µm, in *L. aphaca var. biflorus*, to 52.58 µm, in *L. tukhtensis* (Table 2). Pollen shape varies from spheroidal to prolate (P/E = 1.00-1.57), mostly frequent subprolate in *L. aureus*, *L. brachypterus*, *L. digitatus*, *L. tuberosus, L. chloranthus*, *L. roseus* subsp. *roseus, L. pratensis*, *L. laxiflorus* subsp. *laxiflorus*, *L. czeczottianus*, *L. saxatilis*, and *L. sphaericus*) (Figs. 1a; 2a, g; 3a, g, m; 4a, d, g; 5a, d). Sometimes grain forms coexist between subprolate and prolate in *L. czeczottianus* or between spheroidal and subprolate in *L. incurvus* and *L. tuberosus* (Table 2). According to the equatorial view, the pollen grains can be divided into two groups based on their equatorial view: 1. Quadratic-obtuse-emarginate pollen group in *L. tukhtensis*, *L. cilicicus* and *L. inconspicuus* var. *inconspicuus* (Table 2; Figs. 2j, m; 5g); 2. Elliptical to rectangular-obtuse-convex pollen group in the rest of the taxa (Table 2; Figs. 1a, d; 2a, d, g; 3a, d, g, i, m; 4a, d, g, j, m; 5a, d, j). Moreover, the pollen grains in polar view vary from circular as in *L. incurvus*, *L. chloranthus*, *L. cicera*, *L. laxiflorus* subsp. *laxiflorus*, *L. sphaericus* (Figs. 1e; 3h, j; 4e; 5e); triangular as in *L. hirsutus*, *L. pratensis*, *L. inconspicuus* var. *inconspicuous* (Figs. 3e; 4b; 5h) to penta/hexangular-obtuse-convex as in *L. aureus*, *L. brachypterus*, *L. armenus*, *L. digitatus*, *L. tukhtensis*, *L. cilicicus*, *L. tuberosus and L. nissolia* Figs. 1b; 2b, e, h, k, n; 3b; 5k). They sometimes forms coexist triangular to circular in several taxa, such as *L. aphaca* var. *biflorus* and *L. aphaca* var. *affinis* (Fig. 4k, n).

Apertures

The pollen grains are 3-zonocolporate. In the ectoaperture, the colpi are usually long, narrow, sunken (widely sunken in *L. inconspicuus* var. *inconspicuus*), nearly reaching at the poles, straight, widened from mesocolpium to poles, with acute ends. The length of colpus (Clg) ranges from 22.87 µm, in *L. laxiflorus* subsp. *laxiflorus*, to 42.15 µm, in *L. brachypterus* (Table 2). In the endoaperture, the porus is large, circular or elliptic, protruding in mesocolpium or not. The length of porus (Plg) ranges from 4.02 µm, in *L. hirsutus*, to 19.67 µm, in *L. cilicicus*. The width of porus (Plt) varies from 5.67 µm, in *L. tuberosus*, to 18.98 µm, in *L. cilicicus* (Table 2).

Exine ornamentation

Five different types of surface ornamentation are distinguished at the mesocopium: (1) perforate, (2) finely reticulate-perforate (the most common with 15 taxa), (3) obscurely reticulate-perforate, (4) reticulate-granulate and (5) granulate-perforate (Table 2).

Type 1. Perforate

Observed in *L. tukhtensis* and *L. cilicicus* (Fig. 2l, o).

Type 2. Finely reticulate-perforate

Observed in *L. aureus*, *L. digitatus*, *L. tuberosus*, *L. chloranthus*, *L. roseus* subsp. *roseus*, *L. pratensis*, *L. laxiflorus* subsp. *laxiflorus*, *L. czeczottianus*, *L. aphaca* var. *biflorus*, *L. aphaca* var. *affinis*, *L. saxatilis*, *L. sphaericus* and *L. nissolia* (Figs. 1c; 2i; 3c, o; 4c, f, i, l, o; 5b, c, f, l).

Type 3. Obscurely reticulate-perforate

Observed in *L. incurvus*, *L. brachypterus*, *L. armeus* and *L. hirsutus* (Figs. 1f, 2c, f; 3f).

Type 4. Reticulate-granulate

Observed only in *L. cicera* (Fig. 3k, l).

Type 5. perforate-granulate

Observed in *L. inconspicuus* var. *inconspicuus* (Fig. 5i).

The surface of apocolpium and colpus are psilate or perforate in all taxa except *L. chloranthus* exhibits the finely reticulate-perforate pattern (Fig. 3h). While a sunken apocolpium is recognized only in *L. tukhtensis*, *L. cilicicus* and *L. inconspicuus* var. *inconspicuous*, a widely sunken colpus is observed only in *L. inconspicuus* var. *inconspicuous*.

Table 1. Collection data of *Lathyrus* specimens examined here from pollen morphological point of view. Taxa endemic to Turkey are indicated by an asterix (*).

Taxa	Collection data
L. aphaca var. *biflorus*	B4 Konya: Sultanhanı to Karapınar, 37°44′467″N–33°33′353″E, 994 m, 22.5.2010, *Çildir 123*.
L. aphaca var. *affinis*	A4 Ankara: Kalecik, Kızılırmak riverbank, 40°05′018″N–33°27′088″ E, 638 m, 20.6.2009, *Çildir 118*.
L. armenus	A6 Sivas: Zara to İmranlı, 39°52′985″N–38°03′701″E, 1581 m, 22.6.2010, *Çildir 168*; near Cumhuriyet University, 1247 m, 18.7.2009, *Güneş 2492*.
L. aureus	A4 Ankara: Çubuk, Karagöl, 40°24′775″N–32°54′706″E, 1512 m, 30.5.2010, *Çildir 132*.
*L. brachypterus**	A4 Ankara: Beypazarı to Eğriova, 40°17′960″N–31°58′724″E, 1534 m, 28.6.2009, *Çildir 112*. B5 Aksaray: Hasan Mountain-Helvadere, 1360 m, 9.7.2008, *Güneş 1961*.
L. chloranthus	C4 Konya: Susuz plain, Beyşehir Sultanpınarı, 1097 m. 11. 6.2009, *Güneş 2320*.
L. cicera	B5 Aksaray: Hasan Mountain, 38°10′600″N–34°10′920″E, 1510 m, 23.5.2010, *Çildir 125*. C4 Konya: Hadim-Taşkent road 3 km, 1161 m. 11.6.2009, *Güneş 2316*.
*L. cilicicus**	C4 Karaman: above Ermenek, 36°37′59.76″N-32°54′33.90″E, 1350 m, 27.6.2009, *Celep 1714*.
*L. czeczottianus**	A4 Kastamonu : Ilgaz-Kastamonu ex-road 42. km, 1450 m, 17.7.2009, *Güneş 2475*. B5 Kayseri: Erciyes Mountain, 38°36′907″N–35°30′840″E, 1780 m, 19.6.2010, *Çildir 157*.
L. digitatus	B3 Eskişehir: Mihalıççık, 39°53′588″N–31°27′731″E, 1435 m, 16.6.2010, *Çildir 146*.
L. hirsutus	A4 Ankara: METU, near Biology department, 39°53′461″N-32°46′488″E, 850 m, 6.5.2010, *Çildir 133a*.
L. inconspicuus var. *inconspicuus*	B5 Yozgat: Sorgun to Alaca, 39°54′247″N–34°56′220″E, 1322 m, 24.6.2010, *Çildir 177*.
L. incurvus	A4 Ankara: near Kalecik, 40°05′018″N–33°27′088″E, 638 m, 20.6.2009, *Çildir 118*.
L. laxiflorus subsp. *laxiflorus*	B3 Eskişehir: Yukarı Kalabak village, 39°32′617″N–30°17′614″E, 1127 m, 27.6.2009, *Çildir 108*. C4 Konya: Hadim-Taşkent road 3 km, 1161 m. 11.6.2009, *Güneş 2313*.
L. nissolia	A4 Ankara: Kıcılcahamam, Soğuksu National Park, 40°26′442″N–32°37′272″E, 1392 m, 5.6.2010, *Çildir 141*. C4 Konya: Doğanhisar, Güvenlik village, 1456 m. 12.6.2009, *Güneş 2324*.
L. pratensis	B5 Yozgat: Akdağmadeni to Şarkışla, 39°36′980″N–35°56′425″E, 1586 m, 23.6.2010, *Çildir 173*.
L. roseus subsp. *roseus*	B6 Sivas: Zara to Şerefiye, 39°58′281″N–37°43′434″E, 1639 m, 22.6.2010, *Çildir 162a*.
L. saxatilis	B4 Ankara: near Lalahan, 39°58′043″N–33°07′256″E, 1084 m, 6.5.2009, *Çildir 121*.
L. sphaericus	C4 Konya: Akşehir, Çakıllı village, 1262 m, 12.6.2009, *Güneş 2332*.
L. tuberosus	A4 Ankara: Çubuk, Karagöl, 40°24′775″N–32°54′706″E, 1512 m, 30.5.2010, *Çildir 132a*. C4 Konya: Susuz plain, Beyşehir Sultanpınarı, 1097 m. 11.6.2009, *Güneş 2321*.
*L. tukhtensis**	A4 Çankırı: Çankırı to Eldivan, 40°29′883″N–32°30′248″E, 1216 m, 27.6.2010, *Çildir 179a*; Yapraklı Mountain, 1626 m, 17.7.2009, *Güneş 2487*.

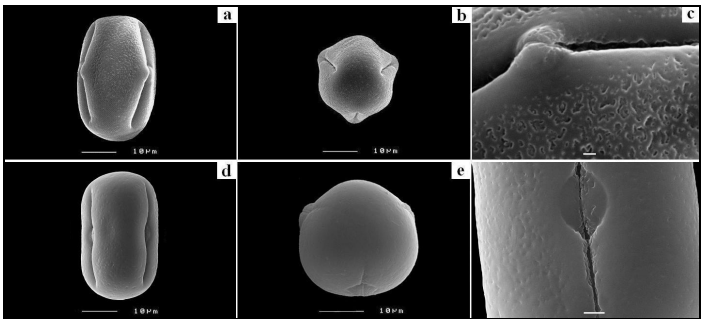

Fig 1. SEM micrographs of pollen grains of the section *Orobus*. *L. aureus* (**a**) equatorial view, (**b**) polar view, (**c**) ornamentation; *L. incurvus* (**d**) equatorial view, (**e**) polar view, (**f**) ornamentation. Scale bars: (c) 1 µm; (f) 10 µm.

Discussion

Tosheva and Tonkov (2005, 2007), Güneş and Aytuğ (2010), Güneş and Çırpıcı (2010) and Güneş (2011a, b) pointed out that pollen morphological characters were valuable for distinguishing the species in *Lathyrus*. The present study is in agreement with this point of view. The results indicate that the surface sculpturing type of the pollen grains, their size, shape and outline in equatorial view can be of taxanomic value in the separation of the studied taxa. However, these characters are shown to be useless in sectional delimitation of the genus.

Systematic usefulness of pollen size

The largest pollen grains (P = 48.08±1.81 µm x E = 46.44±1.89 µm) are found in *L. tukhtensis* from sect. *Lathyrostylis* while the smallest pollen grains (P = 32.98±2.15 µm x E = 24.18±2.02 µm) occur in *L. nissolia* from sect. *Nissolia* (Table 2). Most of the taxa examined by us had more or less similar pollen morphologies to those examined by a few researchers (Tosheva and Tonkov, 2005, 2007; Güneş and Aytuğ, 2010; Güneş and Çırpıcı, 2010; Güneş, 2011a, b), except for the differences in size and ratio of the polar axis to equatorial diameter. The values are a little different from those given in this our study.

Table 2. Summary of pollen morphological data for the taxa studied of *Lathyrus* according to the infrageneric system of Kupicha (1983). All sizes are in µm. Numbers refer to (maximum-minimum) (mean±standard deviation).

Sections	Taxa	P	E	P/E	Ex	Clg	Plg	Plt	Outline in equatorial view	Ornamentation in the mesocolpium
Orobus	*L. aureus*	(47.28-41.23)	(40.48-36.20)	1.19	(1.09-0.82)	(32.89-28.43)	(8.33-5.21)	(7.89-6.08)	Eroc	Finely reticulate-
		(44.77±2.29)	(37.78±1.41)	Sp	(0.92±0.17)	(30.69±1.33)	(7.72±0.63)	(6.96±0.98)		perforate
	L. incurvus	(40.33-30.55)	(34.26-29.91)	1.10	(1.35-0.89)	(31.02-26.80)	(9.92-7.12)	(9.11-6.14)	Eroc	Obscurely reticulate-
		(35.12±1.16)	(31.90±1.13)	S(±Sp)	(1.12±0.23)	(29.48±2.02)	(8.65±0.9)	(8.38±1.02)		perforate
Lathyrostylis	*L. brachypterus*	(48.05-40.29)	(38.66-32.70)	1.18	(1.25-0.98)	(42.15-38.16)	(13.18-8.77)	(18.12-13.78)	Eroc	Obscurely reticulate-
		(43.63±2.23)	(36.97±2.61)	Sp	(1.05±0.16)	(40.24±1.46)	(12.76±2.01)	(16.88±1.21)		perforate
	L. armenus	(39.42-34.54)	(36.31-31.17)	1.11	(1.29-0.86)	(29.78-24.45)	(13.80-9.19)	(16.23-12.56)	Eroc	Obscurely reticulate-
		(36.76±2.05)	(33.17±2.24)	S	(0.98±0.13)	(27.65±2.33)	(10.05±1.23)	(14.57±1.26)		perforate
	L. digitatus	(45.56-40.45)	(33.45-26.89)	1.32	(1.03-0.87)	(30.67-25.35)	(9.28-5.67)	(12.65-8.78)	Eroc	Finely reticulate-
		(42.54±1.13)	(32.23±1.43)	Sp	(0.93±0.14)	(27.24±2.63)	(7.89±1.76)	(10.09±1.31)		perforate
	L. tukhtensis	(54.32-46.15)	(52.58-44.12)	1.04	(1.43-0.85)	(34.65-28.48)	(14.32-10.43)	(18.01-13.99)	Rom	Perforate
		(48.08±1.81)	(46.44±1.89)	S	(1.01±0.14)	(31.19±2.25)	(12.45±2.16)	(16.71±1.45)		
	L. cilicicus	(44.89-40.67)	(45.98-39.67)	1.01	(1.78-1.02)	(41.67-39.98)	(19.67-15.45)	(18.98-14.16)	Rom	Perforate
		(42.19±1.69)	(41.89±1.46)	S	(1.12±0.16)	(40.19±1.35)	(17.47±1.81)	(16.33±1.31)		
Lathyrus	*L. tuberosus*	(48.86-40.15)	(37.95-30.21)	1.14	(1.04-0.87)	(35.65-30.46)	(8.67-4.56)	(9.74-5.67)	Eroc	Finely reticulate-
		(42.08±2.49)	(36.89±1.80)	S(±Sp)	(0.98±0.2)	(33.16±2.78)	(6.78±1.08)	(7.06±1.08)		perforate
	L. hirsutus	(45.36-38.35)	(30.52-23.09)	1.39	(1.32-0.79)	(40.12-36.52)	(9.49-4.02)	(10.09-6.21)	Eroc	Obscurely reticulate-
		(40.87±2.56)	(29.34±2.19)	Pr	(0.95±0.2	(38.28±2.87)	(7.45±1.43)	(7.96±1.21)		perforate
	L. chloranthus	(50.12-44.21)	(41.90-36.01)	1.26	(1.11-0.79)	(37.48-32.82)	(11.04-7.87)	(12.29-9.21)	Eroc	Finely reticulate-
		(46.82±1.96)	(37.16±2.41)	Sp	(0.94±0.15)	(34.76±1.98)	(9.81±1.46)	(10.86±0.99)		perforate
	L. cicera	(48.75-46.20)	(36.92-25.91)	1.38	(1.81-0.98)	(40.55-34.11)	(11.95-9.61)	(11.73-8.54)	Eroc	Reticulate-granulate
		(47.32±1.19)	(34.36±2.03)	Pr	(1.21±0.15)	(37.91±3.27)	(10.86±1.24)	(9.19±1.31)		
Orobon	*L. roseus* subsp.	(46.76-41.90)	(35.16-31.25)	1.30	(1.46-0.98)	(37.41-33.24)	(13.68-9.87)	(12.14-8.41)	Eroc	Finely reticulate-
	roseus	(43.67±2.14)	(33.64±1.73)	Sp	(1.05±0.17)	(35.55±1.18)	(10.08±1.32)	(9.61±1.21)		perforate
Pratensis	*L. pratensis*	(40.67-34.56)	(32.67-26.45)	1.23	(1.34-0.78)	(30.65-24.56)	(9.74-6.06)	(12.34-8.89)	Eroc	Finely reticulate-
		(37.13±2.19)	(30.28±1.66)	Sp	(1.01±0.18)	(27.29±2.79)	(8.91±0.64)	(9.01±0.99)		perforate
	L. laxiflorus	(42.89-36.24)	(33.76-27.34)	1.25	(1.46-0.78)	(27.72-22.87)	(10.34-7.89)	(12.43-8.02)	Eroc	Finely reticulate-
	subsp. *laxiflorus*	(38.25±1.78)	(30.58±2.13)	Sp	(0.94±0.14)	(23.14±2.34)	(8.34±1.12)	(9.21±0.89)		perforate
	L. czeczottianus	(45.67-38.98)	(34.27-29.54)	1.33	(1.05-0.78)	(30.67-25.88)	(11.68-7.89)	(12.19-7.03)	Eroc	Finely reticulate-
		(42.79±1.87)	(32.23±2.09)	Pr(±Sp)	(0.89±0.15)	(27.23±2.13)	(9.04±1.65)	(8.58±0.92)		perforate
Aphaca	*L. aphaca*	(54.06-44.42)	(33.05-20.17)	1.57	(1.01-0.78)	(37.86-34.15)	(9.67-4.89)	(10.31-7.67)	Eroc	Finely reticulate-
	var. biflorus	(46.44±3.67)	(29.54±3.12)	Pr	(0.92±0.19)	(35.78±1.93)	(6.05±1.54)	(9.56±1.35)		perforate
	L. aphaca	(53.15-45.32)	(34.15-28.67)	1.51	(1.02-0.82)	(35.98-30.31)	(8.92±5.43)	(11.73-8.89)	Eroc	Finely reticulate-
	var. affinis	(46.64±3.89)	(30.81±3.08)	Pr	(0.95±0.21)	(32.37±2.01)	(6.16±1.31)	(9.98±1.42)		perforate
Viciopsis	*L. saxatilis*	(40.67-37.21)	(33.01-25.45)	1.24	(1.15-0.98)	(36.34-29.45)	(9.98-4.56)	(10.86-8.35)	Eroc	Finely reticulate-
		(38.89±1.57)	(31.50±1.42)	Sp	(1.02±0.3)	(34.61±2.12)	(6.45±1.76)	(7.76±1.05)		perforate
Linearicarpus	*L. sphaericus*	(47.77-43.27)	(42.32-35.46)	1.16	(0.98-0.67)	(35.78-29.32)	(10.23-6.12)	(13.02-8.31)	Eroc	Finely reticulate-
		(44.81±2.07)	(38.49±2.47)	Sp	(0.91±0.1)	(33.21±2.32)	(8.32±2.65)	(10.11±1.45)		perforate
	L. inconspicuus var.	(34.28-28.67)	(35.79-30.78)	1.00	(1.34-0.93)	(28.54-26.58)	(9.27-7.23)	(11.84-8.09)	Rom	Perforate-granulate
	inconspicuus	(33.57±2.02)	(33.48±1.93)	S	(1.07±0.14)	(27.78±0.96)	(8.25±0.76)	(9.02±1.18)		
Nissolia	*L. nissolia*	(36.81-30.32)	(21.14-28.97)	1.36	(1.11-0.78)	(31.67-25.87)	(11.32-5.34)	(13.07-8.26)	Eroc	Finely reticulate-
		(32.98±2.15)	(24.18±2.02)	Pr	(0.96±0.2)	(27.89±2.42)	(8.91±1.14)	(10.18±1.63)		perforate

Clg = Colpus length, E = equatorial diameter, Eroc = Elliptical to rectangular-obtuse-convex, Ex = Exine thickness, P = Polar diameter, Plg = Porus length regarding the poles, Plt = Porus width regarding the equatorial diameter, Pr = Prolate, Rom= Rectangular-obtuse-emarginate, S = Spheroidal, Sp = Subprolate, ± = pollen shape is rarely present.

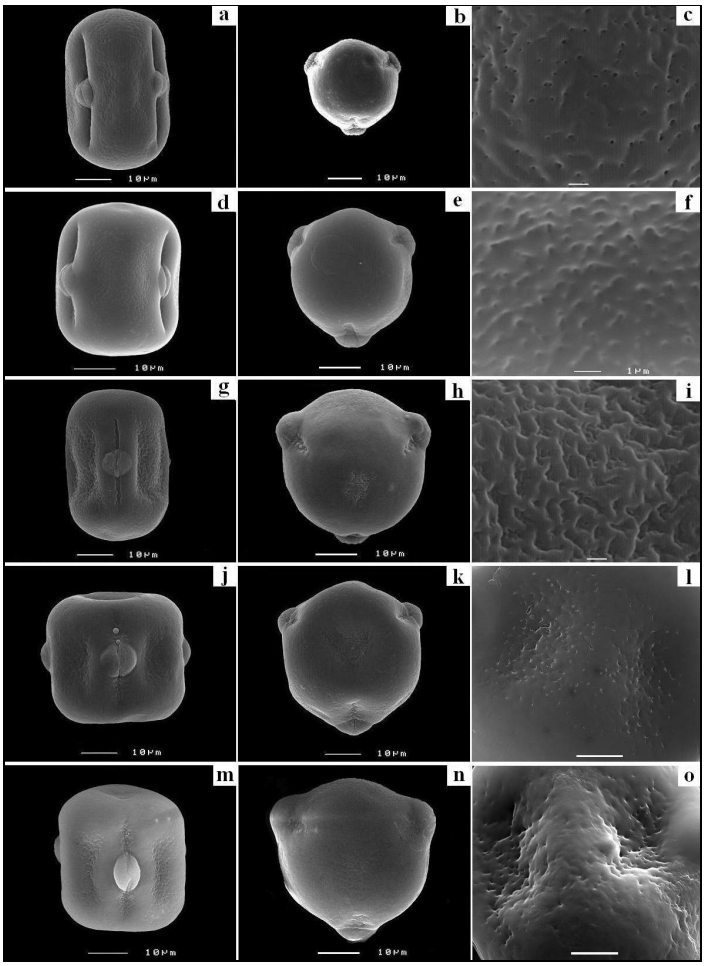

Fig 2. SEM micrographs of pollen grains of the section *Lathyrostylis*. *L. brachypterus* (**a**) equatorial view, (**b**) polar view, (**c**) ornamentation; *L. armenus* (**d**) equatorial view, (**e**) polar view, (**f**) ornamentation; *L. digitatus* (**g**) equatorial view, (**h**) polar view, (**i**) ornamentation; *L. tukhtensis* (**j**) equatorial view, (**k**) polar view, (**l**) ornamentation; *L. cilicicus* (**m**) equatorial view, (**n**) polar view, (**o**) ornamentation. Scale bars: (a, b, d, e, g, h, j, k, m, n) 10 µm; (c, f, i) 1 µm; (l, o) 5 µm.

These minor differences may result from variations in preparation treatments. In the pollen size variability is major and, consequently, the parameters for polar axes and equatorial diameters have a diagnostic value between some of the taxa within the same section, for example, between *L. aureus* and *L. incurvus*, between *L. digitatus* and *L. tukhtensis*, between *L. armenus* and *L. cilicicus*, and between *L. sphaericus* and *L. inconspicuus* var. *inconspicuus*. Based on pollen size and the other examined pollen characters, however, it is impossible to find any important differences between *L. aphaca* var. *biflorus* and *L. aphaca* var. *affinis* belonging to sect. *Aphaca* and between *L. pratensis* and *L. laxiflorus* subsp. *laxiflorus* belonging to sect. *Pratensis*. The sections *Nissolia*, *Orobon* and *Viciopsis* are monotypic (Kupicha, 1983; Asmussen and Liston, 1998; Kenicer et al., 2005). The section *Nissolia* can be distinguished by its smallest pollen grains (P = 32.98±2.15 µm x E = 24.18±2.02 µm) from the other sections studied here. This agrees with the results obtained from previous studies (Moore et al., 1991; Perveen and Qaiser, 1998; Halbritter, 2000; Mantar et al., 2001, 2003; Tosheva and Tonkov, 2005, 2007; Güneş and Aytuğ, 2010; Güneş and Çırpıcı, 2010; Güneş, 2011a, b). However, there appear to be no important pollen morphological differences in distinguishing the sections *Orobon* and *Viciopsis* from the others.

Systematic usefulness of pollen shape

The shape of the pollen grains varies among some of the taxa, even within the same taxon. However, *L. armenus*, *L. tukhtensis*, *L. cilicicus* and *L. inconspicuus* var. *inconspicuus* have always spheroidal pollen grains and *L. hirsutus*, *L. cicera*, *L. aphaca* var. *biflorus*, *L. aphaca* var. *affinis* and *L. nissolia* have always prolate pollen grains. Moore et al. (1991) described two types for *Lathyrus* pollen: the *Vicia cracca* type and the *Lathyrus* type. Beug (2004) presented general description of the pollen morphological characters of taxa assigned to the *Lathyrus* type. This pollen type was characterized by being 3-zonocolporate, prolate (P/E=1.23-1.91) and medium in size (30-50 µm), with suprareticulate ornamentation and lumina reaching up to 2.5-3.0 µm in diameter, unlike the *Vicia* type, where lumina is more than 3.0 µm in diameter. The pollen grains were almost psilate at apocolpium and around the apertures and sometimes the reticulum was not well defined. Each aperture was composed of well-defined circular or elliptic endopori and ectocolpi with heavy thick costae. The exine was 1.0-1.5 µm thick and thinner at apocolpium and the endexine was thicker than the tectum. In *L. filiformis*, *L. pallescens* and *L. pancicii* belong to sect. *Lathyrostylis*, Tosheva and Tonkov (2007) described the *Lathyrus filiformis* type as a third pollen type. In this type, the pollen had a quadratic (rectangular) outline in its equatorial view. Of the *Lathyrus* taxa examined to date (Faegri, 1956; Gapotchka and Chamara, 1972; Gapotchka, 1974; Clarke and Kupicha, 1976; Fergusson and Skvarla, 1981; Faegri and Iversen, 1989; Moore et al., 1991; Perveen and Qaiser, 1998; Halbritter, 2000; Mantar et al., 2001, 2003; Beug, 2004; Tosheva and Tonkov, 2005, 2007; Güneş and Aytuğ, 2010; Güneş and Çırpıcı, 2010; Güneş, 2011a, b), the *Lathyrus filiformis* pollen type was found only in sect. *Lathyrostylis*. Confirming with previous findings our study also shows that this pollen type is found in the pollen grains of *L. tukhtensis* and *L. cilicicus*. Additionally, the *Lathyrus filiformis* type is first identified in the pollen grains of *L. inconspicuus* var. *inconspicuus* from sect. *Linearicarpus*. The other studied taxa have elliptical to rectangular-obtuse-convex pollen grains.

Systematic usefulness of exine ornamentation

The exine ornamentation at the mesocopium proved to be a valuable taxonomic character in *Lathyrus*. It varies from perforate, finely reticulate-perforate, obscurely reticulate-perforate, reticulate-granulate to granulate-perforate. The type of the exine ornamentation is variable within the sections *Orobus*, *Lathyrostylis*, *Lathyrus* and *Linearicarpus*. However, it is constant within the other sections. The finely reticulate-perforate ornamentation is the most frequent type among the examined taxa. The perforate ornamentation is found only in *L. tukhtensis* and *L. cilicicus* (sect. *Lathyrostylis*) whereas the obscurely reticulate-perforate ornamentation is present in *L. incurvus* (sect. Orobus), *L. brachypterus*, *L. armeus* (sect. *Lathyrostylis*) and *L. hirsutus* (sect. *Lathyrus*). *L. cicera* and *L. inconspicuus* var.

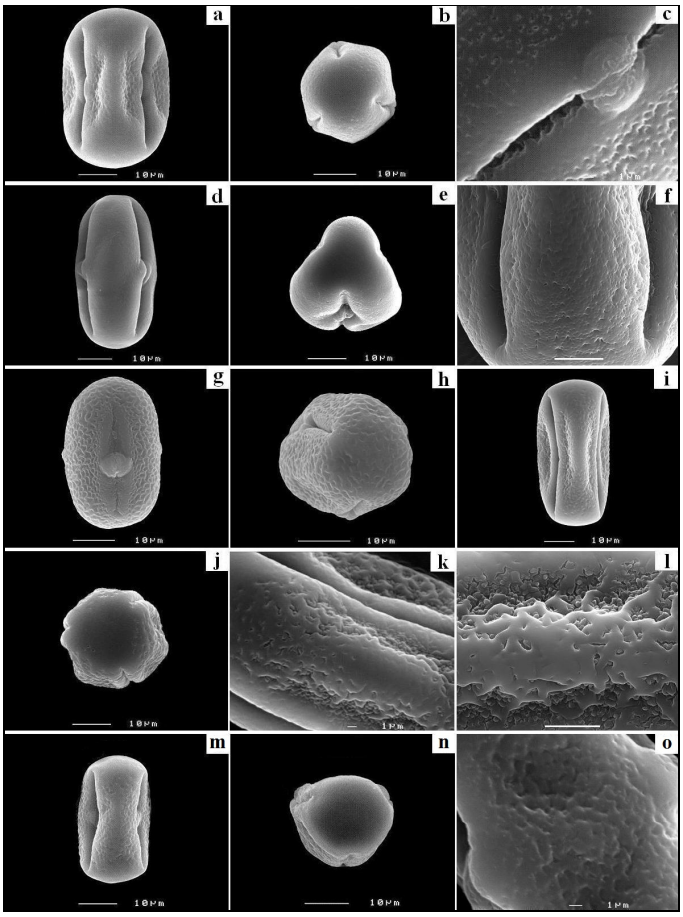

Fig 3. SEM micrographs of pollen grains of the sections *Lathyrus* and *Orobon*. Sect. *Lathyrus*: *L. tuberosus* (**a**) equatorial view, (**b**) polar view, (**c**) ornamentation; *L. hirsutus* (**d**) equatorial view, (**e**) polar view, (**f**) ornamentation; *L. chloranthus* (**g**) equatorial view, (**h**) polar view; *L. cicera* (**i**) equatorial view, (**j**) polar view, (**k-l**) ornamentation. Sect. *Orobon*: *L. roseus* subsp. *roseus* (**m**) equatorial view, (**n**) polar view, (**o**) ornamentation. Scale bars: (a, b, d, e, g, h-j, m, n) 10 µm; (c, k, o) 1 µm; (f, l) 5 µm.

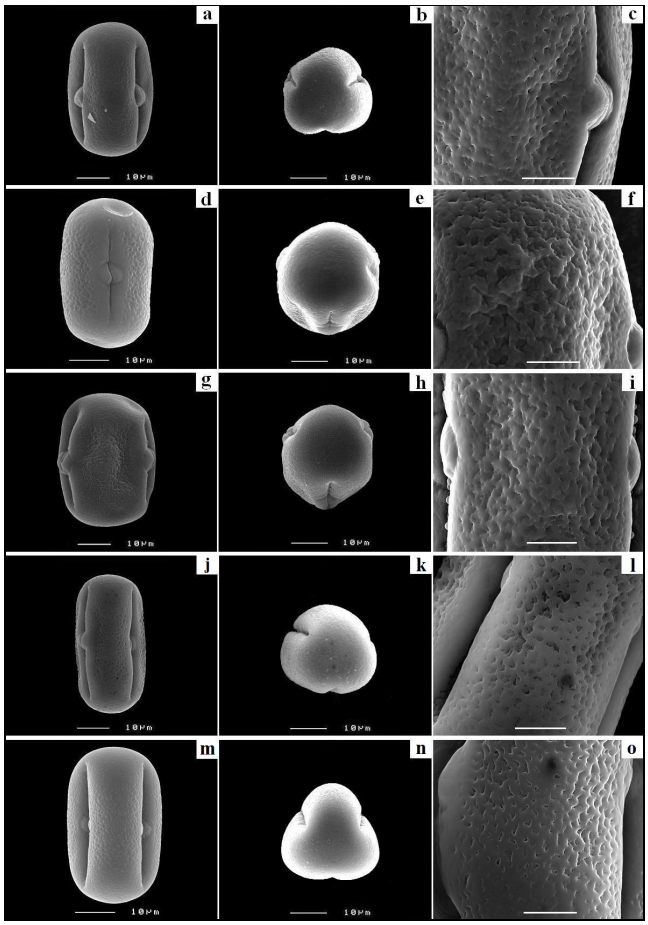

Fig 4. SEM micrographs of pollen grains of the sections *Pratensis* and *Aphaca*. Sect. *Pratensis*: *L. pratensis* (**a**) equatorial view, (**b**) polar view, (**c**) ornamentation; *L. laxiflorus* subsp. *laxiflorus* (**d**) equatorial view, (**e**) polar view, (**f**) ornamentation; *L. czeczottianus* (**g**) equatorial view, (**h**) polar view, (**i**) ornamentation. Sect. *Aphaca*: *L. aphaca* var. *biflorus* (**j**) equatorial view, (**k**) polar view, (**l**) ornamentation; *L. aphaca* var. *affinis* (**m**) equatorial view, (**n**) polar view, (**o**) ornamentation. Scale bars: (a, b, d, e, g, h, j, k, m, n) 10 µm; (c, f, i, l, o) 5 µm.

inconspicuus each exhibit distinct pollen ornamentation types which could not be confused with the pollen of the other taxa studied. *L. cicera* and *L. inconspicuus* var. *inconspicuus* are well characterized by the reticulate-granulate and granulate-perforate ornamentation, respectively. The surface of the apocolpium and colpus area are psilate or perforate in all taxa except *L. chloranthus* show a distinct pollen ornamentation, differing from all other taxa investigated by its the finely reticulate-perforate pattern at the apocolpium. In conclusion, our study on the *Lathyrus* taxa distributed in Central Anatolia indicates that several pollen morphological characters can be utilized as an important tool to distinguish the taxa studied.

though pollen morphology do not provide strong evidence for comparisons at infrageneric level in *Lathyrus*

Material and methods

Plant material

21 taxa of the genus *Lathyrus* were collected from their natural habitats in Central Anatolia, Turkey. The collected specimens were deposited in the herbarium of Department of Biological Sciences, Middle East Technical University (METU), Ankara and Department of Biology, Kafkas University, Kars. The voucher specimens are listed in Table 1.

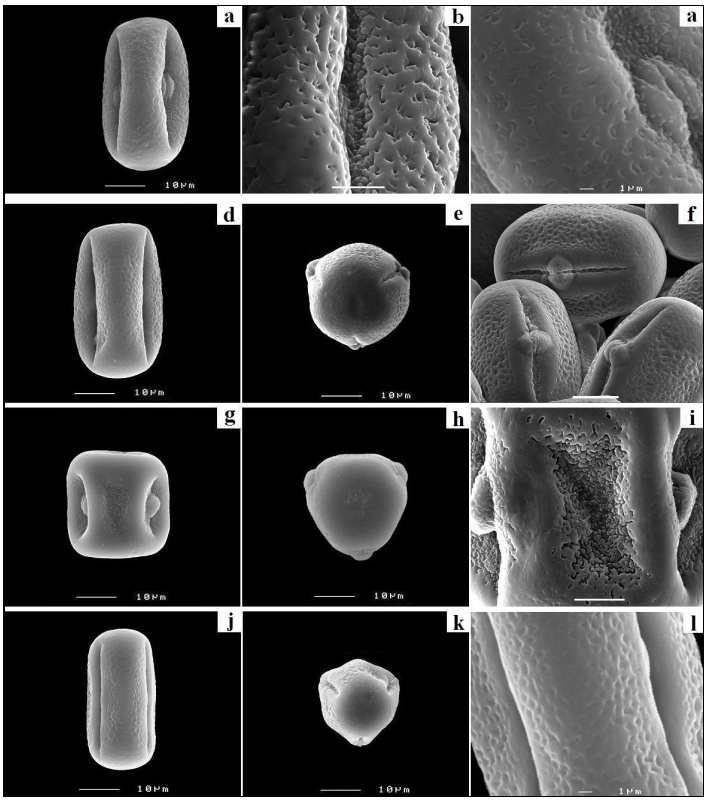

Fig 5. SEM micrographs of pollen grains of *L. saxatilis* in the sections *Viciopsis*, *Linearicarpus* and *Nissolia*. Sect. *Viciopsis*: *L. saxatilis* (**a**) equatorial view, (**b-c**) ornamentation. Sect. *Linearicarpus*: *L. sphaericus* (**d**) equatorial view, (**e**) polar view, (**f**) ornamentation; *L. inconspicuus* var. *inconspicuus* (**g**) equatorial view, (**h**) polar view, (**i**) ornamentation. Sect. *Nissolia*: *L. nissolia* (**j**) equatorial view, (**k**) polar view, (**l**) ornamentation Scale bars: (a, d-h, j, k) 10 µm; (b, i) 5 µm; (c, l) 1 µm.

Light microscopy (LM)

Pollen grains were first treated with 70% alcohol to remove oily substances and then embedded in glycerine jelly stained with basic fuchsin following the method of Wodehouse (1935). Polar axis (P), equatorial axis (E), colpus length (Clg), exine thickness (Ex), porus length (Plg) and porus width (Plt) were measured from 30 fully developed grains per sample under a Leica DMLB2 microscope (1000×). Results are provided as minimum, maximum and mean±standard deviations. P/E ratios were also calculated.

Scanning electron microscopy (SEM)

Pollen grains were transferred directly to stubs with double-sided adhesive tape and micrographs were obtained using Jeol JSM-6400 SEM and Pei Quanta 400F SEM to determine their ornamentation (Doğan, 1988). The terminology follows that of Punt et al. (2007) and Özler et al. (2011).

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