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POLLEN MORPHOLOGICAL STUDIES OF THE GENUS *VERONICA* L. (PLANTAGINACEAE) FROM LESSER HIMALAYAS, PAKISTAN

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Abstract

Pollen morphological characters of 14 species belonging to the genus *Veronica* L. from Lesser Himalayas, Pakistan were studied. All the quantitative and qualitative morphological features of the pollen grains including pollen shape, size, apertures, exine thickness and ornamentation were investigated under light microscope (LM) and Scanning Electron Microscope (SEM). Palynological features of four species (namely *V. biloba, V. pusilla, V. undulata* and *V. stewartii* were studied for the first time. Pollen grains were mostly medium (more than 25µm), rarely (2 spp.) small sized (less than 25µm); prolate-spheroidal (5 spp.), spheroidal (4 spp.), subprolate (2 spp.), prolate (1 sp.), oblate-spheroidal (1 sp.) and oblate (1 sp.), generally free, radially symmetrical, isopolar and tricolpate. Tectum was generally striate (6 spp.), other tectum types viz., rugulate-punctate (4 spp.), rugulate (1 sp.), microreticulate-punctate (2 spp.) and striate-punctate (1 sp.) were also present. Based on exine sculpturing all the species were divided into three groups, viz. *Veronica anagallis aquatica* type having striate sculpturing tectum, *Veronica biloba* type characterized by rugulate sculpturing tectum and micro-reticulate sculpturing tectum. Exine sculpturing (tectum) is an important taxonomic character which could be used for distinguishing species.

Key words: *Veronica*, Tricolpate, Rugulate, Striate pollen.

Introduction

Veronica L. is one of the largest genus in the flowering plant family Plantaginaceae, with 450 species (Albach & Meudt, 2010). Carolus Linnaeus (1753, 1754) described the genus *Veronica*. The genus *Veronica* L., was formerly placed in the family Scrophulariaceae but later it transferred to "Scroph II" and then to family Veronicaceae, after splitting the family Scrophulariaceae based on its polyphyletic nature (proved by molecular investigation) by Olmstead and Reeves (1995), Olmstead *et al*., (2001) and Albach *et al*., (2005). However, International Code of Botanical Nomenclature (ICBN) recognized the name Plantaginaceae Juss., nom. cons. for the family instead of Veronicaceae, (Anon., 2009 and Anon., 2016). However, Öztürk & Kiliç (2016) were of the view that the genus *Veronica* needed to be placed in a separate monotypic family Veronicaceae on the basis of its unique morphological characters and other scientific data.

Most of the *Veronica* species are reported from the temperate Northern Hemisphere. The taxa of the genus are usually herbaceous annuals or perennials, while, subshrubs and shrubs are also present. Stem is erect or prostrate (rhizomatous) with ascending branches, glandular hairy or glabrous. Leaves are mostly opposite, sometimes whorled, sessile to petiolate, blade lanceolate to orbicular, surface glabrous to hairy. Inflorescence terminal or axillary racemes, rarely capitate, flowers bracteate, pedicellate. Calyx mostly 4-lobed. Corolla is also usually 4-lobed, lobes unequal in width and divergent. Stamens 2, fertile, exserted. Capsule usually smooth, slightly to strongly compressed laterally (Ghazanfar *et al*., 2008; Abedin, 2015). Thirty-one (31) species of genus *Veronica* have been reported from Pakistan. Most of them are recorded from Western Himalayas, and Kashmir, Pakistan (Abedin *et al*., 2015).

Risch (1939) studied the pollen of *Veronica* for the first time. Hong (1984) in his palynological study of 19 genera of tribe Veroniceae, including genus *Veronica* and recognized 08 pollen types in the tribe. Fernández *et al*., (1997) investigated pollen morphology of 13 species of *Veronica* from Southwest Spain by light and scanning electron microscope and indicated the eurypalynous nature of the genus. Martiânez-Ortega *et al*., (2000) studied pollen grains of 30 taxa of the genus *Veronica* growing mostly in the Western Mediterranean area by light and scanning electron microscopy (SEM) suggested a close relationship between size of pollen and ploidy level. Saeidi-Mehrvarz & Zarrei (2006) examined the palynological attributes of 17 species of the genus *Veronica* belonging to 5 sections, distributed in Iran by light and scanning electron microscopy (SEM), and recognized three pollen types based on the sculpturing pattern. Kaplan *et al*., (2007) examined the morphology of pollen of 4 species (including 1 endemic species) of the genus *Veronica* from Turkey, by light and scanning electron microscopy (SEM) and discussed similarities and differences among pollen of different taxa. Asmat *et al*., (2011) studied pollen morphology of 7 species belonging to 3 genera viz., *Kickxia*, *Scrophularia* and *Veronica* of the family Scrophulariaceae from Dir valley, Pakistan, by light microscope (LM) and found two different types of pollen on the basis of exine sculpturing. Başer *et al*., (2020) also studied the pollen of 10 species of *Veronica* and reported subprolate to prolate pollen with reticulate, scabrate-perforate and striate-microreticulate tectum.

Palynological information provides highly reliable and permanent characteristics for the delimitation of the taxa, especially, at genus and species level. Therefore, pollen morphological studies are considered as effective tool in taxonomy. Previously published data shows that, little palynological work has been carried out for the genus *Veronica* of the family Plantaginaceae from Pakistan,

particularly from Lesser Himalayas. Therefore, considering Palynology not only provide additional micro-morphological features for correct identification of the current study was carried out but also depicts the relationship among the species so as to assess and distinguish these morphologically related species in a more distinct manner.

Material and Method

Collection and identification of material: Plant specimens were collected from different localities of study area, along with mature flowers. Plants were then properly mounted on standard herbarium sheets and each specimen was identified through available literature, especially Flora of Pakistan (Abedin *et al*., 2015). Already identified specimens present in Hazara University Herbarium (HUP) were also consulted for this purpose. Voucher specimens were deposited in the herbarium (HUP). A list of voucher specimens with their altitudes is given below in (Table 1).

Selection and processing of required material: Polleniferous material (mature anthers or whole flower, in case of small have been described first time, flowers) was excised from collected specimens, and preserved in freshly prepared acetic alcohol. This anthers were crushed and isolated by filtering through glass wool. Pollen grains were separated from filtrate after centrifugation (at 3000-4000 rpm) and washed with water. The pollen material was then treated with 5% potassium hydroxide (KOH) solution and again washed with water and then bleaching was done through chlorination by using conc. H_2SO_4. The material was again washed thoroughly with water to remove any traces of acid and mounted on slides using Glycerin Jelly (stained with 1% Safranine). For each voucher specimen at least 4 to 5 slides were prepared. On an average, thirty to fifty pollen grains of each species were measured.

Photomicrography: Photomicrography (LM) was done in the Department of Botany under "Optika B-193" photomicroscope using Optikam B3 Digital Camera 4083-B3, 3.2 Megapixels, using 10X eyepiece. Later, the prints of desired magnifications were prepared. All the observations on pollen morphology were carried out on research binocular, model: XSZ 107BN, under oil immersion (E100, 1.25), using 10X eyepiece, at Botany Department, Hazara University, data was recorded accordingly and the permanent slides were deposited in herbarium.

The scanning electron microscopy (SEM) was conducted at Central Resource Laboratory, University of Peshawar, on a 30KV Scanning Electron Microscope, JSM 5910, JEOL, Japan. Polleniferous material was prepared in acetic anhydride. The material was then coated with gold in a sputtering chamber (SPI Module Sputter Coater, Model No.11430) before putting in the chamber of SEM. Images of whole pollen and exine sculpturing (tectum) were made and reproduced here.

Terminology: The terminology used is in accordance with Wodehouse (1935), Erdtman (1952), Kremp (1965), Huang (1972), Feagri & Iversen (1975), Punt *et al*., (2007).

Results

General pollen characters of genus *Veronica*: Pollen of 14 species of genus *Veronica* occurring in the area are described here. Pollen grains were small (10-25 µm) to medium (26-50 µm) in size, monad, trizonocolpate, amb circular in polar view and spherical to elliptic in equatorial view, isopolar and centrosymmetrical. Smallest pollen were found in Veronica *peregrina* (20.84 µm) and largest in *V. stewartii* (38.46µm). Shape of the pollen was variable, however, most common shape was prolate-spheroidal (5) followed by spheroidal (4), while other shapes were prolate (1), subprolate (2), oblate (1) and oblate-spheroidal (1). Polar axis was 20.84-38.46 µm long and equatorial axis was 22.04 to 42.64 µm in diameter, colpi length ranged from 16.1 µm to 33.35 µm and width ranging from 7.36 µm to 11.11 µm having blunt ends. Width of mesocolpium ranged from 13.41-27.60 µm. Aperture membrane was granulate in most of the species (11). Exine thickness ranged from 1.0 µm to 2.23 µm, thicker at poles in some (5) species. Tectum was rugulate and striate in most of species, while perforate and micro-reticulate tectum was also observed. In some species, more equatorial than polar views were observed.

On the basis of tectum sculpturing, 03 pollen types were recognized: Type I. *Veronica anagallis aquatic* type; Type II. *Veronica biloba* type and Type III. *Veronica arvensis* type.

Table 1. List of voucher specimens.

S. No	Names of species	Voucher No.	Collection No.	Localities	Altitude	District	Date of collection
1.	*Veronica alpina* subsp. *pumila* (All.) Dostal	HUP-10779	SF-23	Lalazaar	3063m	Mansehra	8th June, 2015
2.	*Veronica anagalloides* Guss.	HUP-10781	SF-61	Chattar-plain	1601m	Mansehra	17th May, 2017
3.	*Veronica anagallis aquatica* L.	HUP-10771	SF-29	Salhad	1149m	Abbottabad	14th April, 2017
4.	*Veronica arvensis* L.	HUP-10776	SF-18	Battagram	1063m	Battagram	24th April, 2016
5.	*Veronica beccabunga* L.	HUP-10766	SF-36	Lulusar lake	3476m	Mansehra	29thAugust,2017
6.	*Veronica biloba* Schreb. ex L.	HUP-10780	SF-19	Jhaffar	1806m	Abbottabad	12th April, 2015
7.	*Veronica laxa* Benth.	HUP-10764	SF-25	Shogran	2370m	Mansehra	9th June, 2015
8.	*Veronica persica* Poir.	HUP-10763	SF-15	Dhodial	994m	Mansehra	26th Feb., 2018
9.	*Veronica peregrina* L.	HUP-10769	SF-22	Shinkiari	1072m	Mansehra	14th May, 2017
10.	*Veronica polita* Fr.	HUP-10777	SF-17	Battagram	1060m	Battagram	14thMarch, 2016
11.	*Veronica pusilla* Kotschy & Boiss.	HUP-10784	SF-62	Shogran	2251m	Mansehra	20th May, 2018
12.	*Veronica serpyllifolia* L.	HUP-10774	SF-63	Mukshpuri top	2810m	Abbottabad	02nd June, 2016
13.	*Veronica stewartii* Penn.	HUP-10782	SF-65	Havelian	916m	Abbottabad	14th April, 2017
14.	*Veronica undulata* Wall.	HUP-10772	SF-28	Khanpur	630m	Haripur	03rd May, 2016

***Veronica anagallis aquatic* type** - This type is characterized by Striate Sculpturing: Tectum mostly striate rarely striate-punctate. Sexine equal to or thicker than nexine. Exine thicker at poles in *Veronica anagallis aquatica*, *V. serpyllifolia* and *V. undulata*. Aperture membrane also ornamented (granulate) in all species, except *Veronica stewartii*. Species included are *Veronica anagalloides,* (Fig. 3-C,D), *V. anagallis-aquatica,* (Fig. 1-A,B; Fig. 3-E,F), *V. beccabunga,* (Fig. 1-H,I; Fig. 3-J,K), *V. pusilla,* (Fig. 2-E,F; Fig. 5-F,G), *V. serpyllifolia,* (Fig. 2-G,H; Fig. 5-C,D,E), *V. stewartii* (Fig. 2-I,J; Fig. 5-A,B) and *V. undulata* (Fig. 2-K,L; Fig. 5-H,I).

***Veronica biloba* type** – This type is characterized by Rugulate Sculpturing**:** Exine ornamentation, mostly rugulate-punctate or rugulate. Sexine as thick as nexine. Exine thicker at poles in *Veronica alpina* subsp. *pumila*. Aperture membrane also ornamented (granulate) in all species. Species included are *Veronica alpina* subsp. *pumila,* (Fig. 3-A,B), *V. biloba,* (Fig. 1-D,E; Fig. 4-A,B), *V. laxa,* (Fig. 1-J, K; Fig. 4-C, D,E), V. persica. (Fig. 1-C; Fig. 4-F, G) and V. polita. (Fig. 2-C, D; Fig. 4-K, L).

***Veronica arvensis* type** – This type is characterized by Micro-reticulate Sculpturing**:** Exine ornamentation, micro-reticulate with various perforations. Sexine mostly thicker than nexine. Exine thicker at poles in *Veronica peregrina*. Aperture membrane ornamented (granulate) in *Veronica arvensis.* Species included are *Veronica arvensis* (Fig. 1-F, G; Fig. 3-G, H, I) and V. *peregrina* (Fig. 2-A,B; Fig. 4-H,I,J).

Based on pollen characters, a key to species has been constructed, which will aid in proper identification of various species belonging to the genus *Veronica*.

Key to species

1 + Tectum striate 2
- Tectum other than striate 8
2 + Tectum strictly striate 3
- Tectum striate-punctate ..... 9. *Veronica beccabunga*
3 + Pollen prolate-spheroidal 4
- Pollen other than prolate-spheroidal 6
4 + Exine thick at poles 5
- Exine not thick at poles ..... 2. *Veronica anagalloides*
5 + Exine less than 1.5 µm thick ..... 12. *Veronica serpyllifolia*
- Exine more than 1.5 µm thick ..... 14. *Veronica undulata*
6 + Pollen spheroidal ..... 11. *Veronica pusilla*
- Pollen other than spheroidal 7
7 + Pollen oblate ..... 13. *Veronica stewartii*
- Pollen prolate ..... 3. *Veronica anagallis aquatica*
8 + Tectum micro-reticulate-punctate 9
- Tectum regulate 10
9 + Pollen prolate-spheroidal, exine thick at poles ..... 9. *Veronica peregrina*
- Pollen spheroidal, exine not thick at poles ..... 4. *Veronica arvensis*
10 + Tectum regulate ..... 7. *Veronica laxa*
- Tectum regulate-punctate 11
11 + Pollen subprolate 12
- Pollen other than subprolate 13
12 + Aperture membrane not ornamented ..... 6. *Veronica biloba*
- Aperture membrane ornamented ..... 8. *Veronica persica*
13 + Pollen shape spheroidal ..... 1. *Veronica alpina* subsp. *pumila*
- Pollen shape Prolate-spheroidal ..... 10. *Veronica polita*

Salient features of the studied species are given, in Tables I and II, while graphs showing statistical ratios are provided in Fig. 6 to Fig. 9.

Discussion

This work includes 14 species belonging to genus *Veronica* of family Plantaginaceae from the study area. Pollen grains were differentiated mainly on the basis of pollen shape and tectum sculpturing. Pollen morphology of 4 species namely *V. biloba, V. pusilla, V. undulata* and *V. stewartii* have been described for the first time. Pollen grains were usually medium rarely small in size, trizonocolpate, isopolar and centrosymmetrical having colpi with blunt ends, while, pollen shape varied from prolate to oblate. Tectum was striate, striate-punctate, rugulate, rugulate-punctate and microreticulate-punctate, where microreticulate-punctate tectum was also observed in small sized pollen. Some previous investigations also showed similar results, such as Martinez-Ortega *et al*., (2000) reported subprolate to oblate-spheroidal, tricolpate pollen among the *Veronica* L., species from Mediterranean, having two types of tectum, i.e., rugulate-reticulate and striate-reticulate tectum. El-Husseini & Shamso (2002), reported pollen grains of *Veronica* L. as tricolpate and usually prolate-spheroidal with striate sculpturing, having granules along colpus membrane, a distinguishing character for various species of *Veronica*. However, in the

present study rugulate sculpturing was also found along with striate sculpturing in some species viz., *V. persica* and *V. polita* and granulate colpal membrane was also common among different species of the genus. Similarly, Saeidi-Mehrvarz & Zarrei (2006) and Kaplan *et al*., (2007) also reported perprolate to oblate-spheroidal, tricolpate pollen in *Veronica* L. Exine ornamentation types were recognized viz., rugulate-perforate, microreticulate, striate-reticulate and scabrate, which showed the eurypalynous nature of the genus *Veronica*. These results were similar with present findings of Agudo *et al*., (2009) who described pollen of 30 species of *Veronica* L., as isopolar, oblate-spheroidal to prolate, usually tricolpate but rarely tetra- to hexacolpate or pantocolpate pollen, colpi acute, with finely granular-verrucate colpal membrane and recognized 03 types of pollen based on pollen sculpturing, i.e., finely striate-reticulate, finely scabrate-perforate and micro rugulate-perforate. However, in the present study the pollen of all the 14 species were tricolpate. Aguda *et al.*, (2009) also suggested that the pollen shape and exine ornamentation were taxonomically important characters. They also reported prolate-sheroidal pollen with striate-reticulate tectum in *V. arvensis* (Aguda *et al*., 2009); while present study showed that pollen of *V. arvensis* were spheroidal with micro-reticulate tectum. Similarly, pollen of *V. anagalloides, V. beccabunga* and *V. anagallis-aquatica* were reported as oblate-sheroidal with striate-reticulate tectum (Aguda *et al*., 2009), while present study showed slight differences in pollen shape, i.e., prolate-speroidal, spheroidal and prolate respectively, with striate tectum. Agudo *et al*., described pollen of *V. persica* as tri-, tatra-, hexa- and pantocolpate (9-colpate), however, present study showed that pollen of these species were exclusively tricolpate. Asmat *et al*., (2011) reported tricolpate with psilate sculpturing in the species of *Veronica* L., (*V. anagallis-aquatica, V. melissifolia* and *V. persica*) while present study showed that pollen of *V. anagallis-aquatica* had striate sculpturing, pollen of *V. laxa* (syn. *V. melissifolia*) had rugulate sculpturing and pollen of V. persica had rugulate-punctate sculpturing, using SEM.

According to Hong (1984) pollen studies are very important in the taxonomy of *Veronica* L., at genus level. Saeidi-Mehrvarz and Zarrei (2006) described exine sculpturing in genus *Veronica* as a valuable character in delimitation of closely related species within the genus. Martinez-Ortega *et al*., (2000) and Agudo *et al*., (2009) founded a close relationship between ploidy level and pollen size in genus *Veronica*, i.e., bigger pollen size represented higher ploidy level, while exine sculpturing was also important at specific level, with striato-reticulate ornamentation as most common. However, pollen size seemed to play important role in delimitation of perennial and some annual species of *Veronica* as well. Present study also showed two groups of pollen in terms of pollen size, i.e., small and medium. Kaplan *et al*., (2007) confirmed the evolutionary trends observed by Martinez-Ortega *et al*., (2000) in pollen sculpturing of the genus *Veronica* from rugulate to striate.

Table I (Exine sculpturing).

S. No.	Name of species	No of Colpi	Colpus (µm)		Thickness (µm)				Mesocolpium	Sculpturing
			Length	Width	Exine	Sexine	Nexine	Intine	Width(µm)	
1.	*Veronica alpina* subsp. *pumila*	3	24.15	8.05	1.93	0.96	0.96	-	17.88	Rugulate-punctate
2.	*Veronica anagalloides*	3	22.01	9.49	1.42	0.75	0.67	-	17.68	Striate
3.	*Veronica anagallis aquatica*	3	30.09	9.20	1.30	0.65	0.65	-	15.52	Striate
4.	*Veronica arvensis*	3	25.16	8.56	1.5	0.76	0.73	-	15.90	Microreticulate-punctate
5.	*Veronica beccabunga*	3	20.7	10.64	1.70	-	-	1.0	18.59	Striate-punctate
6.	*Veronica biloba*	3	27.10	7.36	1.03	-	-	-	19.16	Rugulate-punctate
7.	*Veronica laxa*	3	23.90	11.11	1.42	0.74	0.68	-	18.97	Rugulate
8.	*Veronica persica*	3	33.35	7.57	1.55	0.80	0.75	-	14.52	Rugulate-punctate
9.	*Veronica peregrina*	3	16.1	8.21	1.70	0.86	0.83	-	13.41	Microreticulate-punctate
10.	*Veronica polita*	3	22.80	10.35	1.20	-	-	-	16.67	Rugulate-punctate
11.	*Veronica pusilla*	3	18.63	8.81	1.43	0.76	0.66	-	17.04	Striate
12.	*Veronica serpyllifolia*	3	22.10	8.62	1.0	0.5	0.5	-	18.78	Striate
13.	*Veronica stewartii*	3	18.92	10.02	2.23	1.33	0.90	-	27.60	Striate
14.	*Veronica undulata*	3	19.80	7.86	1.75	0.87	0.87	-	16.96	Striate

Table II (Pollen shapes)

S. No	Name of specimen	Pollen class	Polar Axis (µm)		Equatorial Axis (µm)		P/E Ratio	Pollen shape
			Mean	Range	Mean	Range		
1.	*Veronica alpina* subsp. *pumila*	monad, tricolpate	27.31	24.15-32.2	27.69	23.0-35.65	1.014	Spheroidal
2.	*Veronica anagalloides*	monad, tricolpate	27.46	23.0-31.05	28.75	23.0-27.6	1.047	Prolate-spheroidal
3.	*Veronica anagallis aquatica*	monad, tricolpate	27.34	25.3-32.2	37.99	31.05-44.85	1.39	Prolate
4.	*Veronica arvensis*	monad, tricolpate	22.59	18.4-25.3	22.76	20.7-29.9	1.00	Spheroidal
5.	*Veronica beccabunga*	monad, tricolpate	26.83	23.0-29.9	26.74	21.85-32.2	0.99	Spheroidal
6.	*Veronica biloba*	monad, tricolpate	25.87	20.7-29.9	32.2	23.0-35.65	1.24	Subprolate
7.	*Veronica laxa*	monad, tricolpate	32.96	27.6-34.5	30.90	24.15-36.8	0.94	Oblate-spheroidal
8.	*Veronica persica*	monad, tricolpate	32.91	24.15-36.8	42.64	41.4-46.0	1.30	Subprolate
9.	*Veronica peregrina*	monad, tricolpate	20.84	18.4-23.0	22.04	18.4-25.3	1.06	Prolate-spheroidal
10.	*Veronica polita*	monad, tricolpate	26.40	23.0-32.2	28.47	20.7-32.2	1.08	Prolate-spheroidal
11.	*Veronica pusilla*	monad, tricolpate	29.09	25.3-32.2	29.37	23.0-34.5	1.00	Spheroidal
12.	*Veronica serpyllifolia*	monad, tricolpate	30.66	25.3-34.5	31.09	20.7-34.5	1.01	Prolate-spheroidal
13.	*Veronica stewartii*	monad, tricolpate	38.46	23.0-50.6	27.28	20.7-39.1	0.71	Oblate
14.	*Veronica undulata*	monad, tricolpate	25.62	18.4-32.2	26.93	23.0-29.9	1.05	Prolate-spheroidal

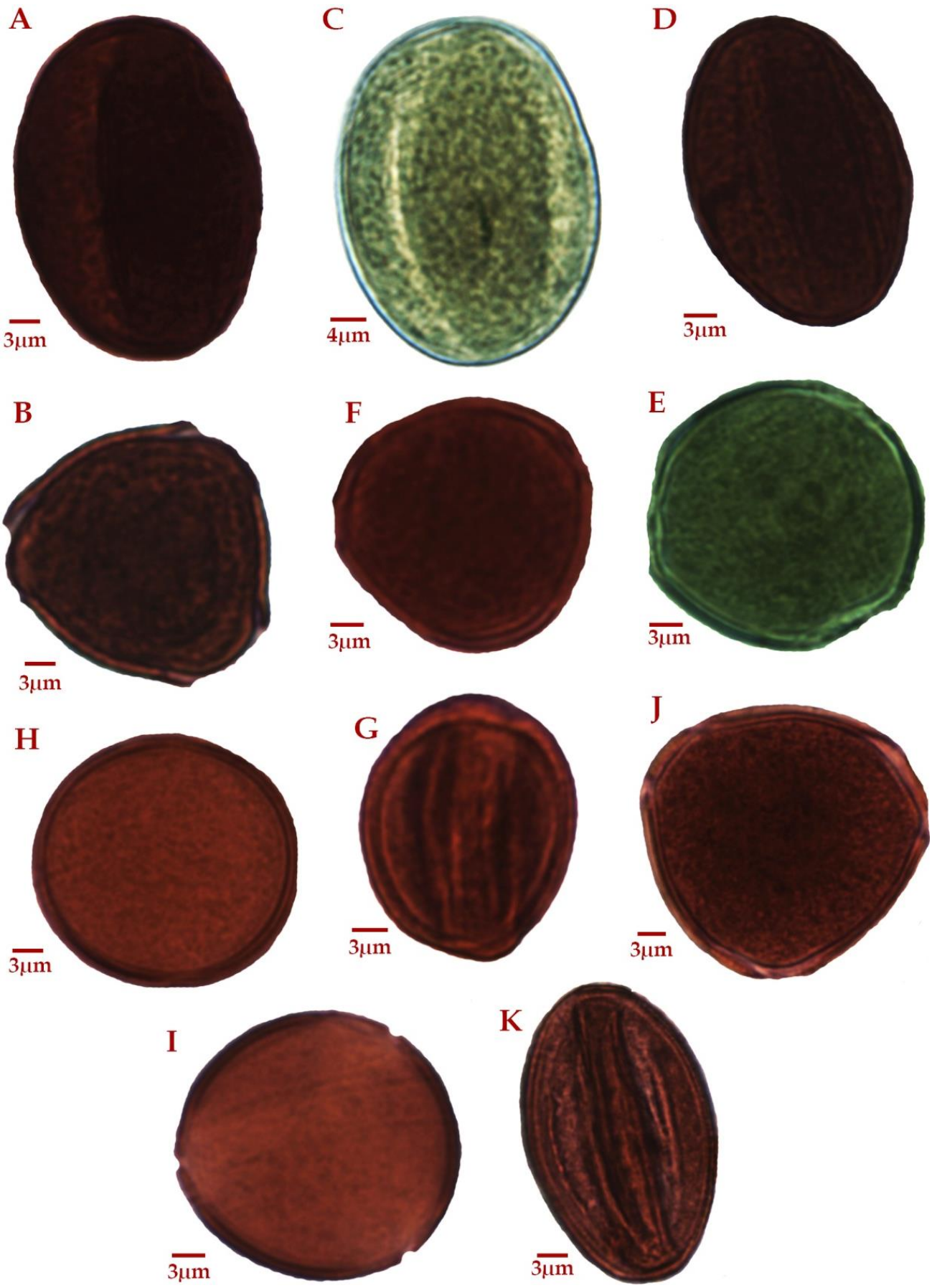

Fig. 1. (LM of pollen), *Veronica anagallis-aquatica:* A, polar view, B, equatorial view; V. persica: C, equatorial view; *V. biloba:* D, equatorial view, E, polar view; *V. arvensis:* F, polar view; G, equatorial view; *V. beccabunga:* H, equatorial view, I, polar view; *V. laxa:* J, polar view, K, equatorial view.

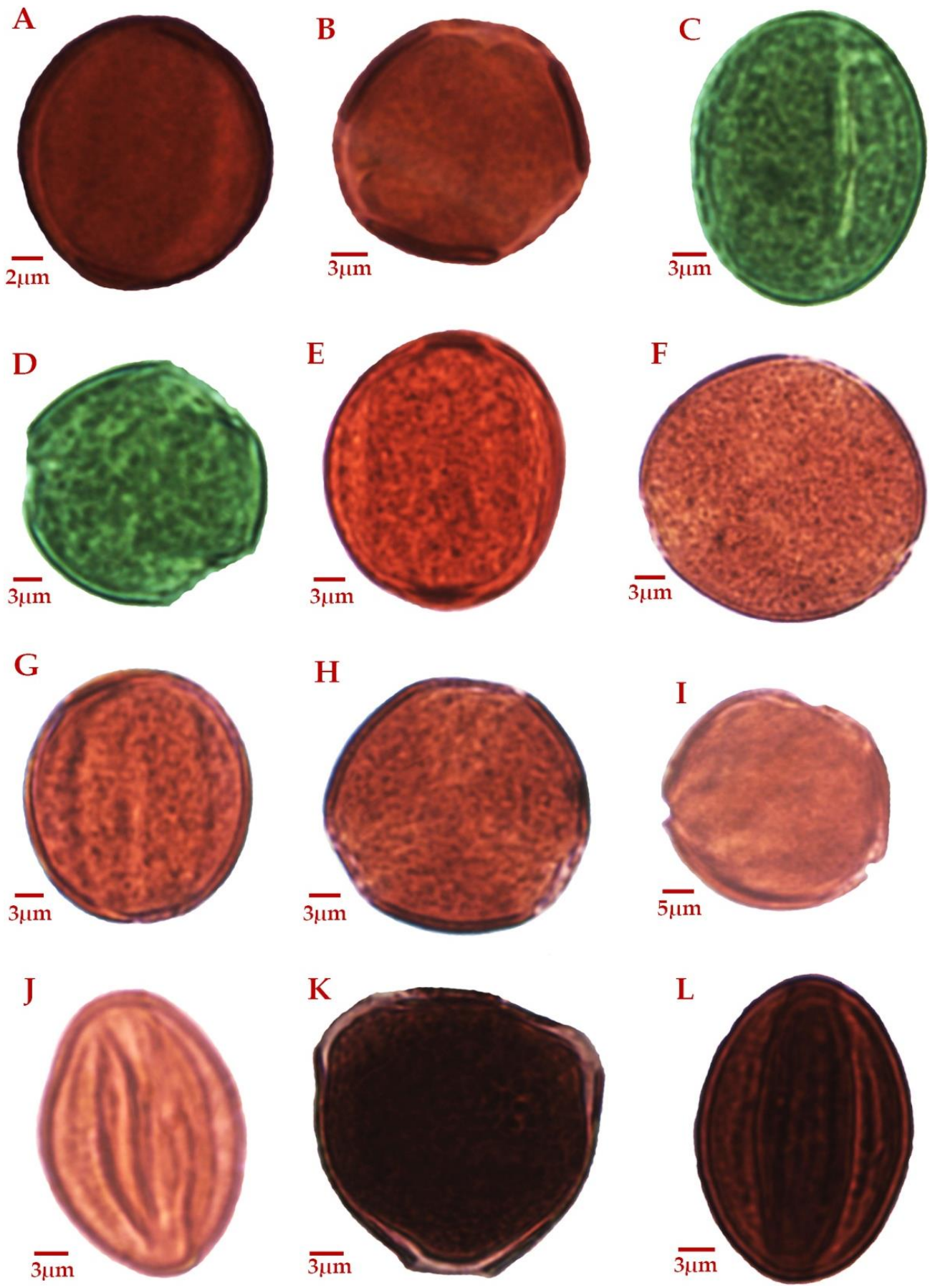

Fig. 2. **(LM of pollen),** *Veronica peregrina:* **A**, equatorial view, **B**, polar view; V. polita: **C**, equatorial view, **D**, polar view; *V. pusilla:* **E**, equatorial view, **F,** polar view; *V. serpyllifolia:* **G,** equatorial view, **H**, polar view; *V. stewartii:* **I**, polar view, **J**, equatorial view; *V. undulata:* **K**, polar view, **L**, equatorial view.

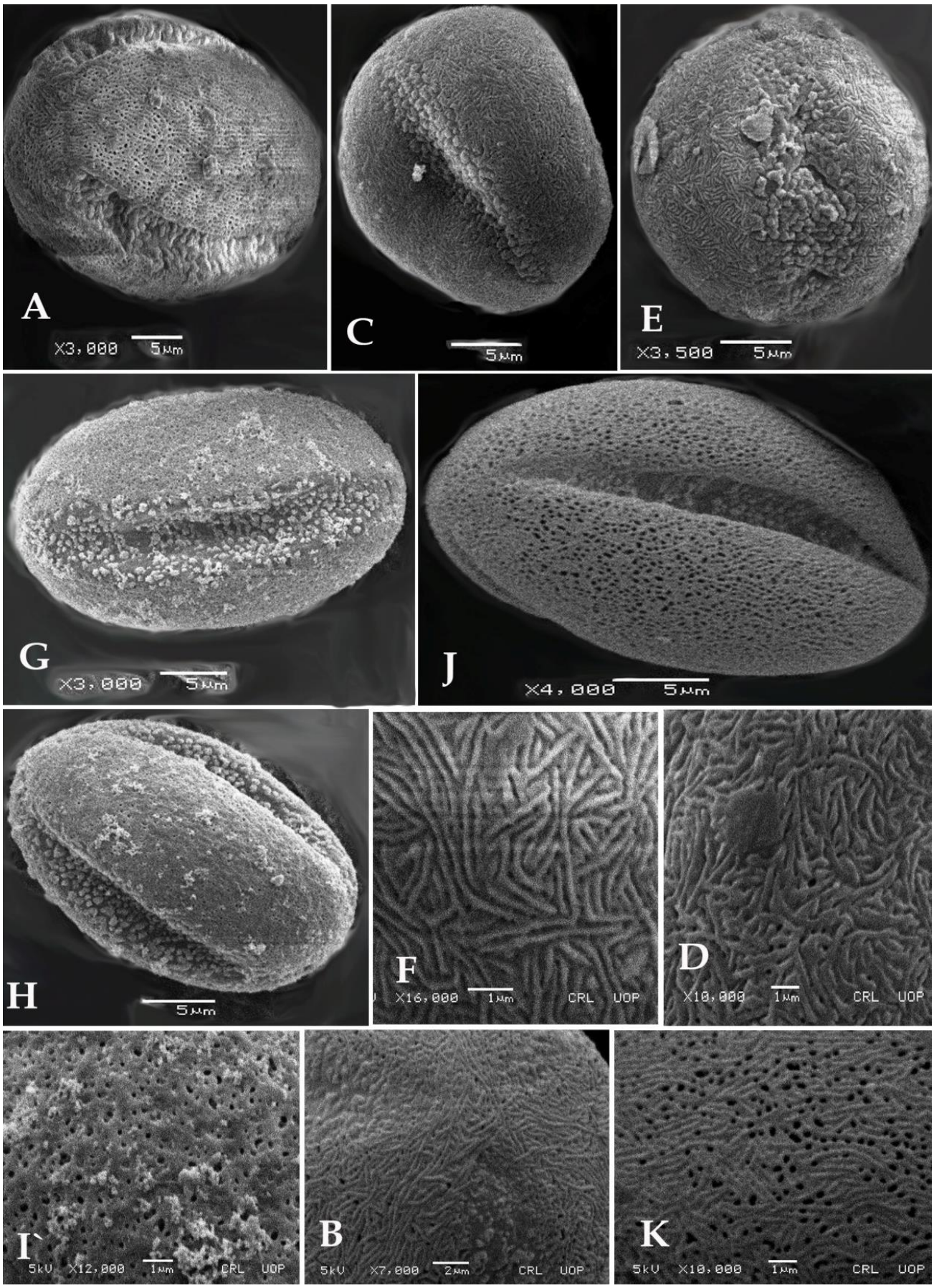

Fig. 3. **(SEM of pollen),** *Veronica alpina* subsp. *pumila:* **A**, equatorial view, **B**, exine ornamentation; *V. anagalloides:* **C**, equatorial view, **D,** exine ornamentation; *V. anagallis-aquatica:* **E**, equatorial view, **F**, exine ornamentation; *V. arvensis:* **G**, equatorial view, **H**, polar view, **I**, exine ornamentation; *V. beccabunga:* **J**, equatorial view, **K,** exine ornamentation.

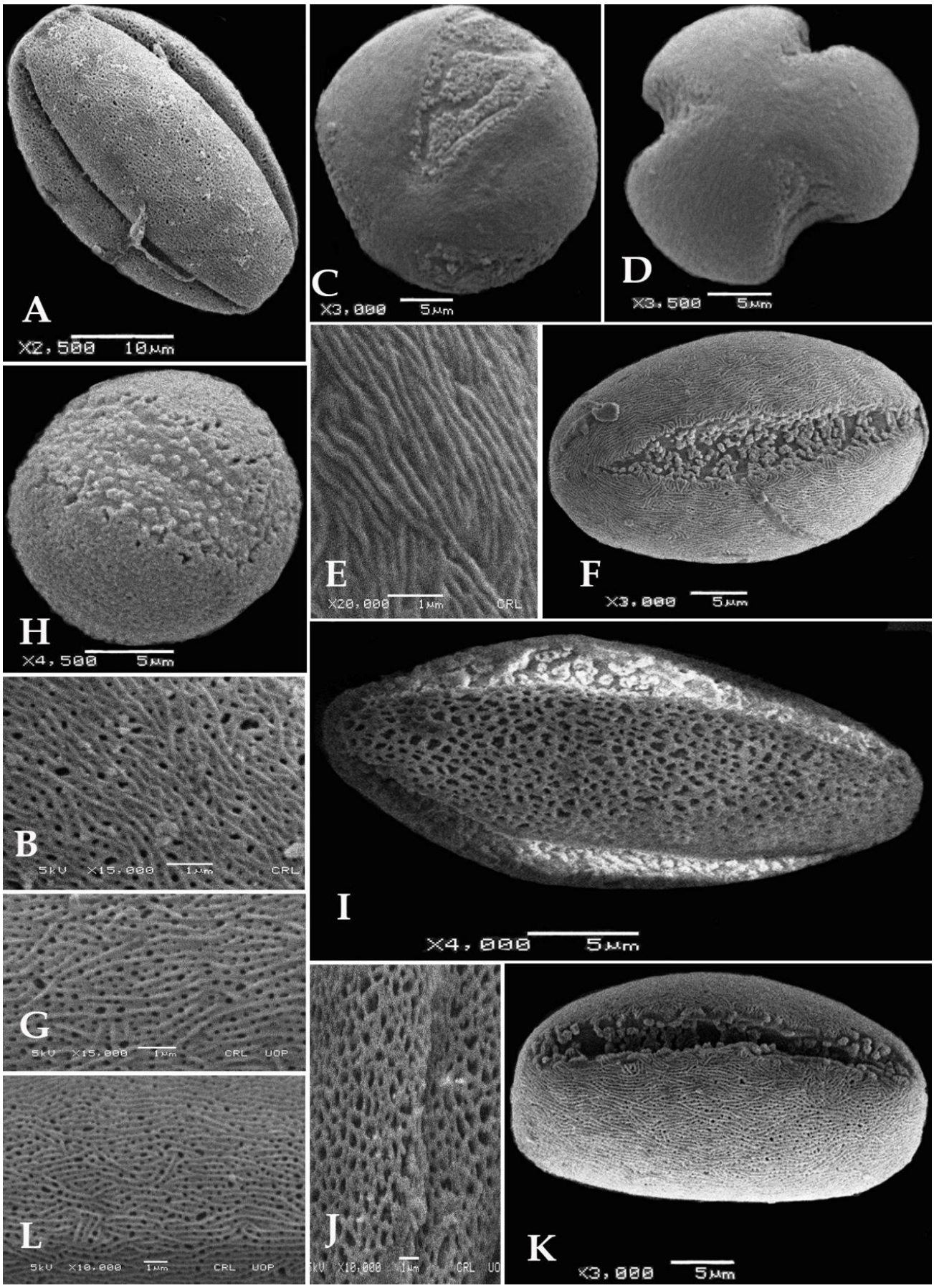

Fig. 4. **(SEM of pollen),** *Veronica biloba:* **A**, equatorial view, **B**, exine ornamentation; *V. laxa:* **C**, equatorial view, **D,** polar view, **E**, exine ornamentation; *V. persica:* **F**, equatorial view, **G**, exine ornamentation; *V. peregrina:* **H**, polar view, **I**, equatorial view, **J**, exine ornamentation; *V. polita:* **K**, equatorial view, **L,** exine ornamentation.

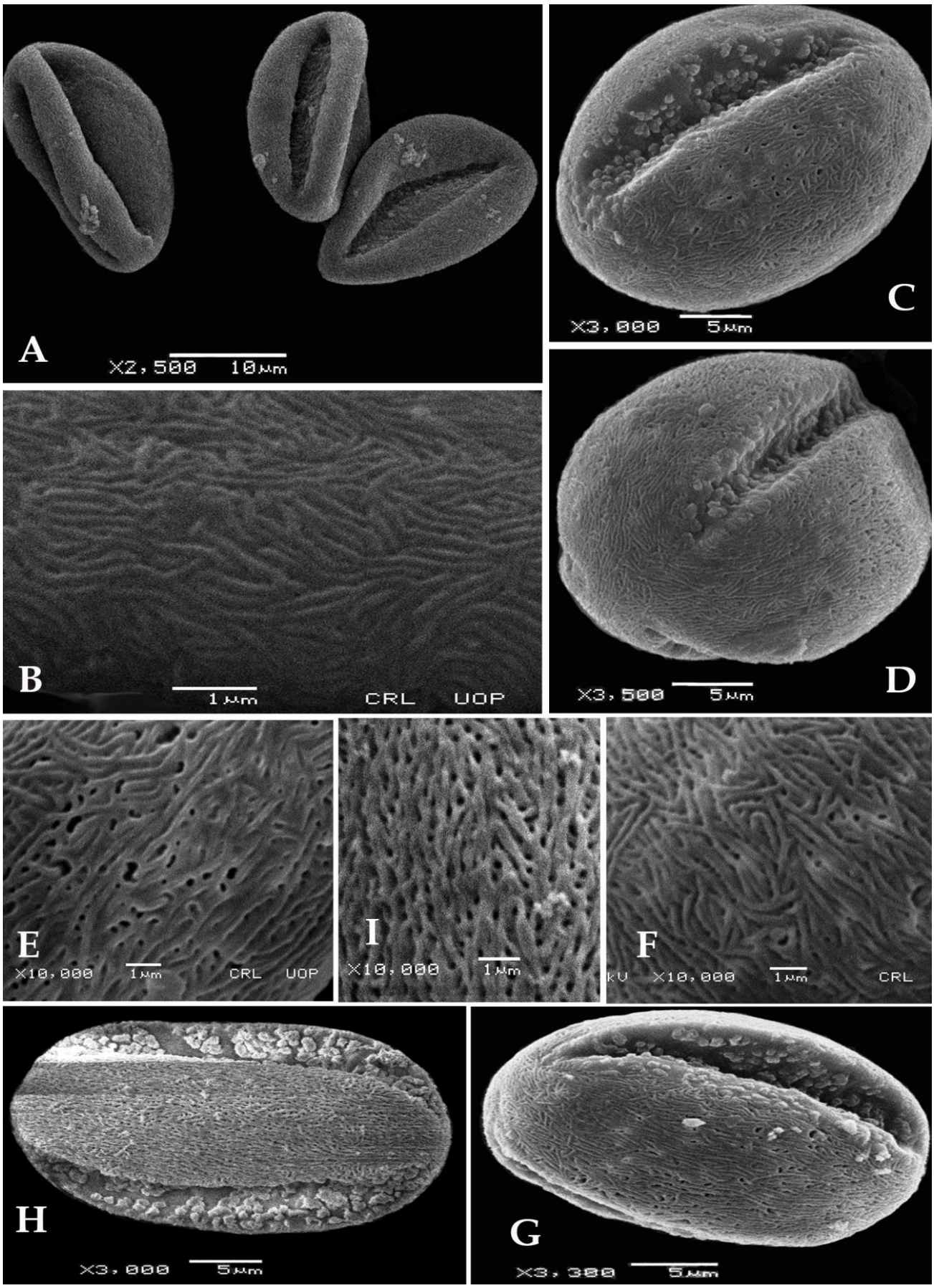

Fig. 5. **(SEM of pollen),** *Veronica stewartii:* **A**, equatorial view, **B**, exine ornamentation; *V. serpyllifolia:* **C,** equatorial view, **D,** polar view, **E**, exine ornamentation; *V. pusilla:* **F**, exine ornamentation, **G**, equatorial view; *V. undulata:* **H**, equatorial view, **I**, exine ornamentation.

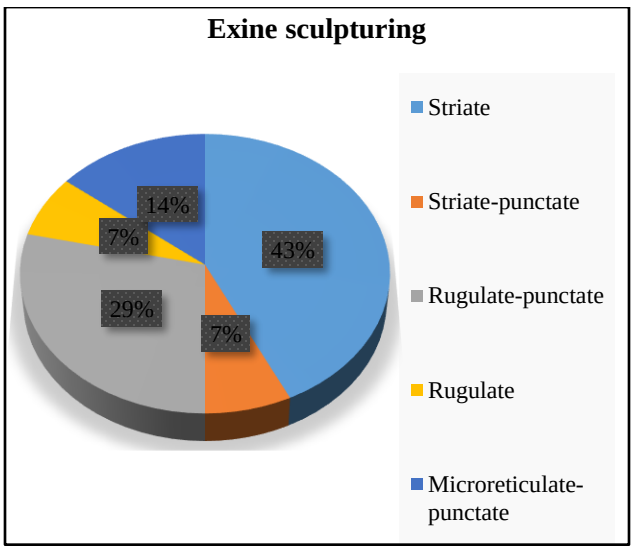

Fig. 6. Exine sculpturing of pollen of the studied species.

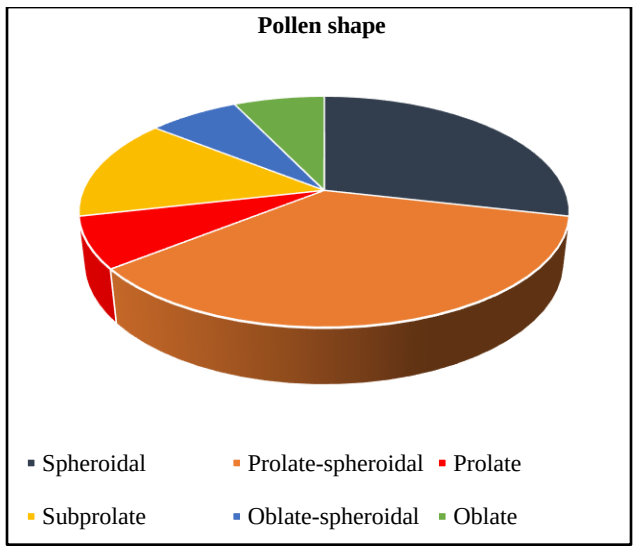

Fig. 7. Pollen shape variation of the studied taxa.

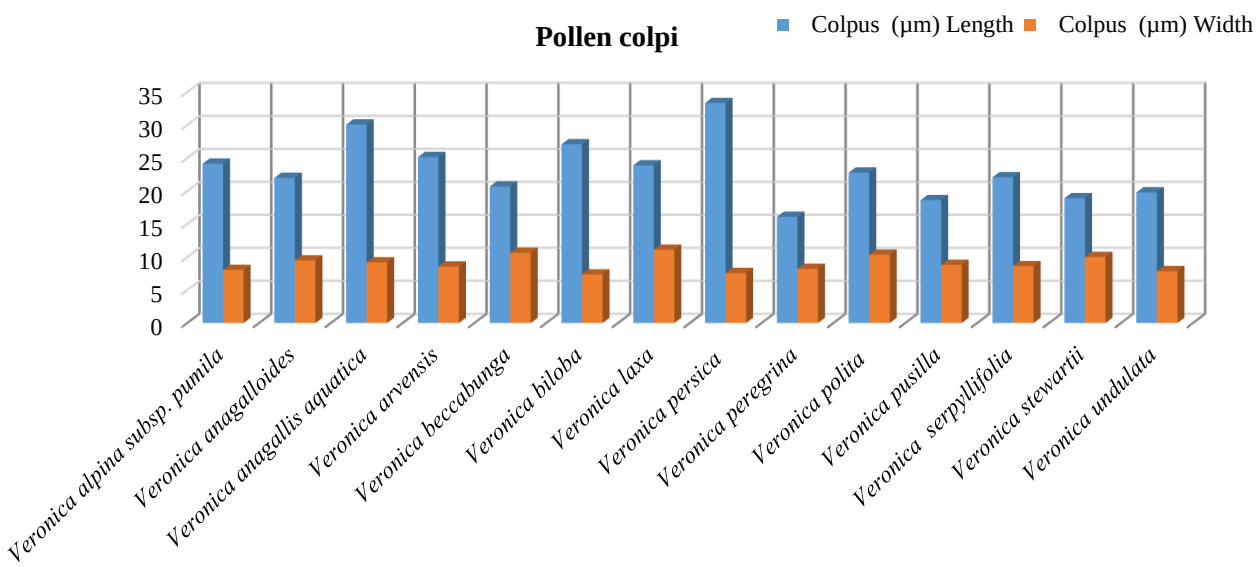

Fig. 8. Pollen colpi-length & width of the studied species.

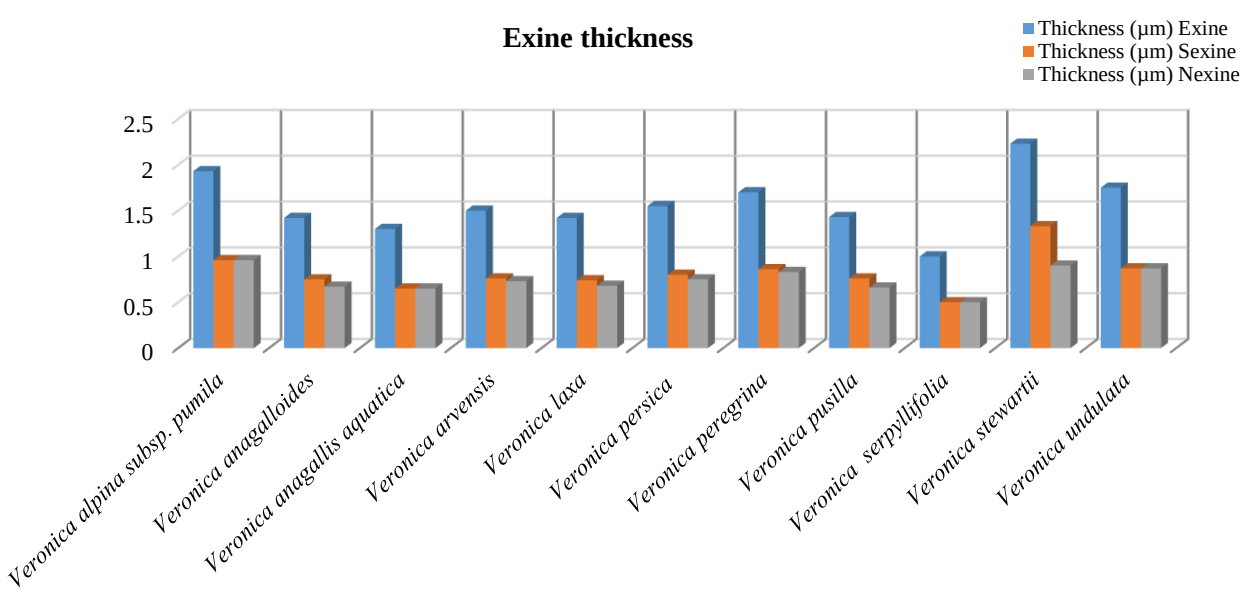

Fig. 9. Exine thickness of pollen of studied species.

Conclusion

Palynological characters like pollen morphology play an important role in delimitation of species. Four (4) species are being described palynologically for the first time. Exine sculpturing is mostly striate, while, other tectum types are also found in the genus. Exine sculpturing proved to be helpful particularly within the genus, like, striate, regulate and micro-reticulate sculpturing. The study has resulted in the development of basic pollen bank of the genus *Veronica* growing in Lesser Himalayan region, including catalogue highlighting micro-morphological traits, which would be useful for future studies. None of the pollen was found to be involved in causing allergy, so their cultivation is quite safe for ornamental as well as medicinal purposes.

Recommendations

Transmission Electron Microscopy should be applied in order to have a more clear picture of exine sculpturing. The genus needs to be investigated at molecular level, i.e., DNA sequencing, for developing the link between molecular characters and morphological features.

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References

Abedin, S., M. Qaiser and G.R. Sarwar. 2015. *Veronica* in Scrophulariaceae: In: (Eds.): Ali, S.I. and M. Qaiser. *Flora of Pakistan*. No. 220: 272-310. Centre for plant conservation, University of Karachi.

Agudo, J.A.S., E. Rico, J. Sánchez and M.M. Martínez-Ortega. 2009. Pollen morphology in the genus *Veronica* L. (Plantaginaceae) and its systematic significance. *Grana*, 48: 239-257.

Albach, D.C., H.M. Meudt and B. Oxelman. 2005. Piecing Together the "New" Plantaginaceae. *Amer. J. Bot.*, 92(2): 297-315.

Albach, D.C. and H.M. Meudt. 2010. Phylogeny of Veronica in the Southern and Northern Hemispheres based on plastid, nuclear ribosomal and nuclear low-copy DNA. *Mol. Phylogen. Evol.*, 54: 457-471.

Anonymous. 2009. Angiosperm Phylogeny Group. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. *Bot. J. Linn. Soc*., 161 (2): 105-121.

Anonymous. 2016. Angiosperm phylogeny classification of flowering plants (APG IV) with the families organized alphabetically within orders. 2016. *Bot. J.,* https://doi.org/10.1111/boj.12385

Asmat, T., M.A. Khan, M. Ahmad and M. Zafar. 2011. Studies on the Pollen Morphology of the Genus *Kickxia*, *Scrophularia* and *Veronica* (Scrophulariaceae) from Dir Valley, Pakistan. *Int. J. Life Sci. Med. Sci*., 1: 9-12.

Başer, B., S. Kocaman and M. Kurşat. 2020. Pollen morphology of the some taxa belonging to *Veronica* L. (Plantaginaceae) and Its taxonomic importance. *Biol. Divers. Conser*., 13(3): 274-281.

El-Husseini, N. and E. Shamso. 2002. Pollen Atlas of the flora of Egypt 5. Species of Scrophulariaceae. *Taeckholmia*, 22: 65-76.

Erdtman, G. 1952**.** Pollen morphology and plant taxonomy: (Angiosperms. An introduction to Palynology-I) Almqvist and Wiksell, Stockholm.: 539.

Faegri, K. and J. Iverson. 1975. Text Book of Pollen Analysis. 3rd revised edition by Faegri, K. 295 Seiten, 31 Abb., 13 Tab. Munksgaard, Copenhagen, Denmark.: 1-295.

Fernández, I., R. Juan and J. Pastor. 1997. *Morfología polínica de Veronica* L. (*Scrophulariaceae*) en el suroeste de España. *Acta Bot. Malacit*., 22: 65-72.

Ghazanfar, S.A., F.N. Hepper and D. Philcox. 2008. Scrophulariaceae, Flora of Tropical East Africa.

Hong, D.Y. 1984. Taxonomy and evolution of the Veroniceae (*Scrophulariaceae*) with special reference to palynology. Copenhagen: Counc. *Nord. Publ. Bot. Opera Bot*., 75.

Huang, T.C. 1972. Pollen flora of Taiwan. National Taiwan University, Botany Department Press: 297: l-177.

Kaplan, A., A. Hasanoglu and I.A. Ince. 2007. Morphological, Anatomical and Palynological properties of some Turkish *Veronica* L. Species (*Scrophulariaceae*), *Int. J. Bot*., 3: 23-32.

Kremp. G.O.W. 1965. Morphologic Encyclopaedia of Palynology. The University of Arizona Press. Tucson: 263.

Linnaeus, C. 1753. Species Plantaram. Vol. 1. London, P: 776-778.

Linnaeus, C. 1754. Genera Plantarum. Ed. V: 83. London.

Martiânez-Ortega, M.M., J.S. Saânchez and E. Rico. 2000. Palynological study of *Veronica* Sect. Veronica and Sect. Veronicastrum (*Scrophulariaceae*) and its taxonomic significance. *Grana,* 39: 21-31.

Olmstead, R.G. and P.A. Reeves. 1995. Evidence for the polyphyly of the Scrophulariaceae based on chloroplast rbcL and ndhF sequences. *Ann. Miss. Bot. Garden*, 82: 176-193.

Olmstead, R.G., C.W. dePamphilis, A.D. Wolfe, N.D. Young, W.J. Elisons and P.A. Reeves. 2001. Disintegration of the Scrophulariaceae. *Amer. J. Bot.*, 88: 348-361.

Öztürk, A. and Ö. Kiliç 2016. In which family shall we put the genus *Veronica* L.? *Unified Jurnal of Bot*., Vol 1(1):001- 009.

Punt, W., P.P. Hoen, S. Blackmore, S. Nilsson and A. Le Thomas. 2007. Glossary of pollen and spore terminology. *Rev.*, *Palaeobot. Palynol*., 143: 1-81.

Risch, C. 1939. Die Pollenkörner der in Deutschland wild wachsenden Scrophulariaceen. *Ver. Dtsch. Bot. Ges*., 57: 108-121.

Saeidi-Mehrvarz, S. and M. Zarrei. 2006. Pollen morphology of some species of the genus *Veronica* (Scrophulariaceae) in Iran. *Wulfenia*. 13: 1-10.

Wodehouse, R.P. 1935. Reprinted in 1965 Pollen Grains: Their structure, identification and significance in science and medicine. Hafner Publishing Co. New York and London.: 574.

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