



Pollen morphology of the some taxa belonging to *Veronica* L. (Plantaginaceae) and Its taxonomic importance

Birol BAŞER^{*1}, Sedat KOCAMAN², Murat KURŞAT¹

ORCID: 0000-0002-9305-8759; 0000-0002-4227-5171; 0000-0002-0861-4213

¹ Bitlis Eren Üniversitesi, Biyoloji Bölümü, 13000, Bitlis, Turkey

² Bitlis Eren Üniversitesi, Fen Bilimleri Enstitüsü Biyoloji ABD, 13000, Bitlis, Turkey

Abstract

In this study, the genus *Veronica* L. (Plantaginaceae) from the Plantaginaceae family *Veronica bozakmanii* M.A.Fisch., *Veronica triphyllos* L., *Veronica persica* Poir., *Veronica triloba* Opiz., *Veronica anagallis-aquatica* L., *Veronica oxycarpa* Boiss., *Veronica cinerea* Boiss. & Balansa., *Veronica macrostachya* Vahl. subsp. *mardinensis* (Bornm.) M. A. Fisch., *Veronica orientalis* L. subsp. *orientalis*, *Veronica orientalis* L. subsp. *nimrodi* (Richt. ex Stapf) M.A. Fisch taxa were investigated in terms of palynological features. The specimens of this taxa were collected during the field surveys were investigated using Light Microscope (LM) and Scanning Electron Microscope (SEM). As a result of this study some common traits of the taxa found out such as pollen tectate, the pollen shapes being subprolate, prolate and the symmetry being heteropolar. Also, the type of the aperture is tricolpate. The SEM microphotographs shows that the ornamentations are reticulate, scabrate-perforate and striate-microreticulate.

Key words: Plantaginaceae, pollen morphology, SEM, *Veronica*

----- * -----

Veronica L. (Plantaginaceae) cinsine ait bazı taksonların polen morfolojileri ve onun sistematik önemi

Özet

Bu çalışmada Plantaginaceae familyasından *Veronica* L. (Plantaginaceae) cinsine ait *Veronica bozakmanii* M.A.Fisch., *Veronica triphyllos* L., *Veronica persica* Poir., *Veronica triloba* Opiz., *Veronica anagallis-aquatica* L., *Veronica oxycarpa* Boiss., *Veronica cinerea* Boiss. & Balansa., *Veronica macrostachya* Vahl. subsp. *mardinensis* (Bornm.) M. A. Fisch., *Veronica orientalis* L. subsp. *orientalis*, *Veronica orientalis* L. subsp. *nimrodi* (Richt. ex Stapf) M.A. Fisch taksonlarının palinolojik özellikleri açısından incelenmiştir. Bu taksonlara ait örnekler yapılan arazi çalışmalarında toplanmıştır. Bu cinse ait taksonlar IM ve SEM kullanılarak incelenmiştir. Bu çalışma sonucunda polenin tektat, polen şekillerinin subprolat, prolat olması ve simetrisinin heteropolar olması gibi bazı özellikler bulunmuştur. Ayrıca SEM mikrofotografaları da ornamentasyon yapılarının retikulat, skabrat-perforat ve striat-mikroretikulat olduğunu göstermiştir.

Anahtar kelimeler: Plantaginaceae, polen morfoloji, SEM, *Veronica*

1. Introduction

Plantaginaceae includes 94 genera and 1900 species throughout the world [1]. *Veronica* L. is a multifarious genus of *Veronicaceae* sensu Angiosperm Phylogeny Group with approximately 450 species in the world. It is commonly distributed throughout the North and South Hemispheres. The taxa of this genus have a high ecological variety and they exist in many different habitats from arid steppes to freshwaters and from sea level to high alpine regions [2]. *Veronica* L. genus is a member of Plantaginaceae sensu APG previously included in Scrophulariaceae [3]

* Corresponding author / Haberleşmeden sorumlu yazar: Tel.: +905427430485; Fax.: +904342229143; E-mail: baser2007@gmail.com

and in addition, they have transferred *Antirrhinum* L., *Calceolaria* L., *Digitalis* L., *Gratiola* L., *Limnophila* R., *Linaria* Mill., *Lindernia* All., *Nemesia* Vent., *Penstemon* Schmid., *Scoparia* L. and *Veronica* L. genera, which were included in Scrophulariaceae, to Plantaginaceae family based on molecular criteria [4; 5].

Veronica was represented with 89 taxa in Turkey before [6]. However, the taxon number of *Veronica* has reached to 107 by the addition of several new taxa; 35 of these taxa are endemic, so the endemism rate is 33% in Turkey [7; 8; 9; 10; 11].

The first description of *Veronica* pollen has been performed by Risch [12]. Also, recent studies have given an idea about the morphological variety in *Veronica* pollen and the genera belonging to it [13; 14]. 19 species of *Veroniceae* family, including 49 species, has been examined using SEM and LM [15]. The pollen morphology of 13 species of *Veronica* genus in southwest Spain has been examined using LM and SEM. This study demonstrates the eurypalinous structure of the genus. Due to exine ornamentation of pollens, two morphological types have been identified: rugulate and scabrate [16]. The pollen morphology of 17 species has been examined and three different outer shell ornaments (rugulate-perforate, microreticulate and psilate) have been defined [17].

Purpose of this study is to provide detailed palyno-morphological properties of 10 taxa belonging to the genus *Veronica* L. by using SEM and LM.

2. Materials and methods

In this article, the samples used are taxa belonging to *Veronica* genus collected from Elazığ and Bitlis provinces.

Specimens investigated: *Veronica bozakmanii*; B8-Bitlis, eastern slopes of mount Kambos, 27.03.2014, 38° 19' 29.58" K, 42° 00' 33.33" D, 1400-1600 m, M. Karataş 1594, Det. M. Kürşat. *Veronica triphyllos*; B7-Elazığ: Baskil, Yukarımahalle hamlet, slopes, 1650-1800m. 1650 m, M. Karataş 1522, Det. M. Kürşat. *Veronica anagallis-aquatica*; B8-Bitlis, northern slopes of mount Kambos, Step, 38° 19' 23.26" K, 41° 59' 42.29" D, 1800-1950 m, M. Karakaş 1500, Det. M. Kürşat. *Veronica oxycarpa*; B8-Bitlis, Northern Slopes of Mount Kambos, Ağaçköprü village, stream edges, 38° 20' 11.95" K, 42° 00' 10.88" D, 1350-1450, M. Karakaş 1963, Det. M. Kürşat. *Veronica orientalis* subsp. *orientalis*; B7-Baskil, Bolucuk hamlet and surroundings, garden interiors, 1580 m, M. Kürşat 7002, Det. M. Kürşat. *Veronica cinerea*; B7-Elazığ: Sivrice, Gözeli Plain, between Şirinyazı-Kamışlık Mountain and Field Edge, 1600-1650 m, M. Kürşat 7005, Det. M. Kürşat. *V. triloba*; B7 Elazığ: Baskil, Bolucuk hamlet sub-places, Quercus area, 1410-1480 m, M. Kürşat 7004, Det. M. Kürşat. *V. persica*; B7- Elazığ: Baskil, Hacımustafa south of village, hillsides, 1750-1950 m, M. Kürşat 7007, Det. M. Kürşat. *Veronica orientalis* subsp. *nimrodi*; B7- Elazığ: Sivrice, Reeds Mountain, Tarlatepe Village Surroundings, Slopes, 1450-1760 m, M. Kürşat 7003, Det. M. Kürşat. *Veronica macrostachya* subsp. *mardinensis*; B7- Elazığ: Baskil, Bolucuk hamlet and surroundings, garden interiors, 1580 m, M. Kürşat 7008, Det. M. Kürşat.

Pollen slides were prepared using Wodehouse [18]. The pollen in the preparations prepared by using wodehouse method was examined morphologically with x100 immersion objective magnification in Olympus BX-3 light microscope. The microphotographs of the pollens were taken with an Olympus BX-41 microscope by taking their equatorial and polar views. SEM microphotographing performed to view the surface of pollens in detail and examine their apertures was performed in ZEISS supra 55 Electron microscope. The terminologies of Hesse et al. [19] were followed.

3. Results

Palynomorphological features of *Veronica* in Tables 1 and Figures 1-2-3. *Veronica* are monad, radially symmetrical, isopolar, prolate-spheroidal, prolate and subprolate with the polar axes 21.95–45.26 µm and the equatorial diameters 15.61–35.58 µm (Table 1). Their dimensions are smaller in *V. orientalis* L. subsp. *orientalis* and larger in *V. triloba* Opiz. The outline of all pollen grains is circular in equatorial view and triangular in polar view; intersemiangular (Table 1; Figures 1-2-3). The pollen grains of *Veronica* are trizonocolpate. Colpus is long (18.69–38.32 µm) and narrow or broad (4.75–7.60 µm); margins distinct, regular and ends acute. Aperture membrane ornamented (Table 1; Figures 1-2-3). The exine ranges from 0.90 to 0.99 µm. The intine is 0.36–0.51 µm thick. *V. bozakmanii* M.A.Fisch. exine sculpturing is reticulate. The number of lumina per 1 µm² is 8-9, the size of the lumina of the pollen grains is approximately 0.77 µm, and the average thickness of the muri is 0.37 µm The reticula are heterobrachate. *V. triphyllos* L. exine sculpturing is scabrate-perforate. The number of scabrae per 1 µm² is 5; scabrae width 0.13 µm, scabrae length 0.20 µm. The number of perforae per 1 µm² is 4. Exine sculpturing is striate-microreticulate in all investigated other species (Table 1; Figures 1-2-3).

Table 1. Palynomorphological parameters of *Veronica* Genus

Taxon	P (μm)	E (μm)	P/E ratio	Ex (μm)	In (μm)	clt (μm)	clg (μm)	Or
<i>V. bozakmanii</i>	40.16 \pm 2.99	31.35 \pm 2.54	S	0.98 \pm 0.11	0.51 \pm 0.19	5.91 \pm 1.09	31.43 \pm 3.56	Re
<i>V. triphyllos</i>	32.74 \pm 3.77	25.39 \pm 3.53	S	0.90 \pm 0.19	0.49 \pm 0.16	6.00 \pm 1.09	25.25 \pm 2.24	Sc-per
<i>V. persica</i>	34.37 \pm 2.67	22.78 \pm 2.46	P	0.92 \pm 0.13	0.38 \pm 0.13	6.49 \pm 0.79	27.78 \pm 4.22	St-mr
<i>V. triloba</i>	45.26 \pm 3.03	35.58 \pm 3.37	S	0.99 \pm 0.11	0.43 \pm 0.18	7.42 \pm 0.84	38.32 \pm 3.36	St-mr
<i>V. anagallis - aquatica</i>	27.65 \pm 4.02	22.02 \pm 4.55	S	0.97 \pm 0.12	0.37 \pm 0.16	5.38 \pm 1.39	22.61 \pm 3.49	St-mr
<i>V. oxicarpa</i>	23.96 \pm 1.05	17.96 \pm 1.23	P	0.94 \pm 0.13	0.42 \pm 0.13	4.75 \pm 0.51	19.84 \pm 0.75	St-mr
<i>V. cinerea</i>	28.26 \pm 4.19	21.26 \pm 3.12	P	0.95 \pm 0.12	0.42 \pm 0.17	5.55 \pm 0.77	23.34 \pm 3.27	St-mr
<i>V. macrostachya</i> subsp. <i>mardinensis</i>	36.62 \pm 3.17	25.87 \pm 2.48	P	0.94 \pm 0.13	0.43 \pm 0.17	6.03 \pm 1.02	32.39 \pm 3.54	St-mr
<i>V. orientalis</i> subsp. <i>orientalis</i>	21.95 \pm 1.59	15.61 \pm 1.20	P	0.93 \pm 0.13	0.36 \pm 0.13	4.75 \pm 0.68	18.69 \pm 1.35	St-mr
<i>V. orientalis</i> subsp. <i>nimrodi</i>	33.26 \pm 3.01	29.51 \pm 2.58	P-s	0.95 \pm 0.12	0.45 \pm 0.15	7.60 \pm 1.31	26.67 \pm 2.05	St-mr

P: Polar axis, **E:** Equatorial diameter, **P-s:** Prolate-spheroidal, **S:** Subprolate, **clg:** Colpus longitude(length), **clt:** Coplus latitude(width), **Ex:** Exine thickness, **In:** Intine thickness, **Or:** Ornamentation, **Sc-per:** Scabrate-perforate, **St-mr:** Striate-microreticulate, **Re:** reticulate

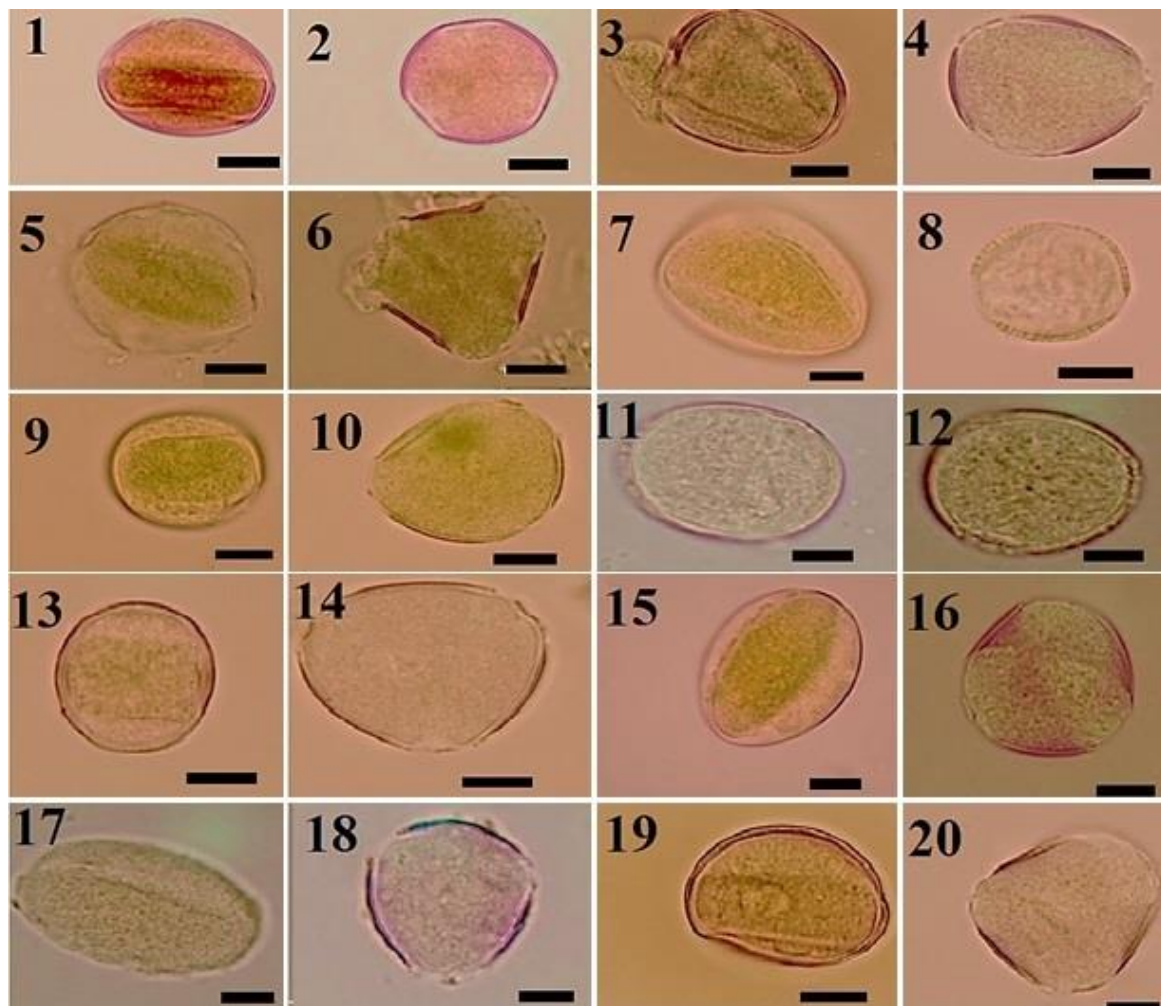


Figure 1. Pollen morphology of *Veronica* by light microscopy. (1-2) *V. bozakmanii*, (3-4) *V. triphyllos*, (5-6) *V. persica*, (7-8) *V. triloba*, (9-10) *V. anagallis-aquatica* (11-12) *V. oxicarpa*, (13-14) *V. cinerea*, (15-16) *V. macrostachya* subsp. *mardinensis*, (17-18) *V. orientalis* subsp. *orientalis*, (19-20) *V. orientalis* subsp. *nimrodi* (scale bar 10 μm)

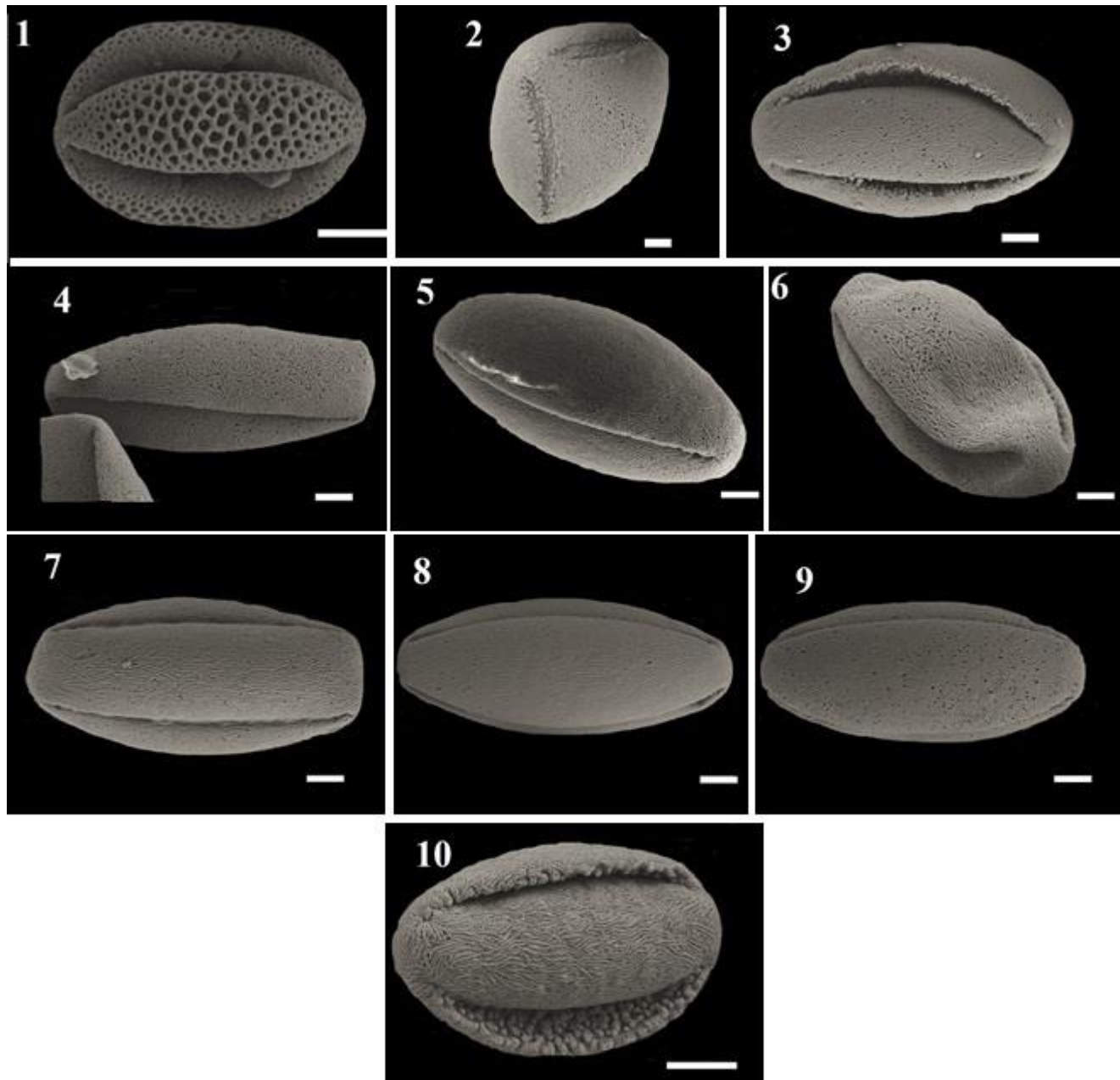


Figure 2. Pollen morphology of *Veronica* by scanning electron microscopy (General view). 1-*V. bozakmanii*, 2-*V. triphyllos*, 3-*V. persica*, 4-*V. triloba*, 5-*V. anagallis-aquatica*, 6-*V. oxycarpa*, 7-*V. cinerea*, 8-*V. macrostachya* subsp. *mardinensis*, 9-*V. orientalis* subsp. *orientalis*, 10-*V. orientalis* subsp. *nimrodi* (scale bar 1 μm)

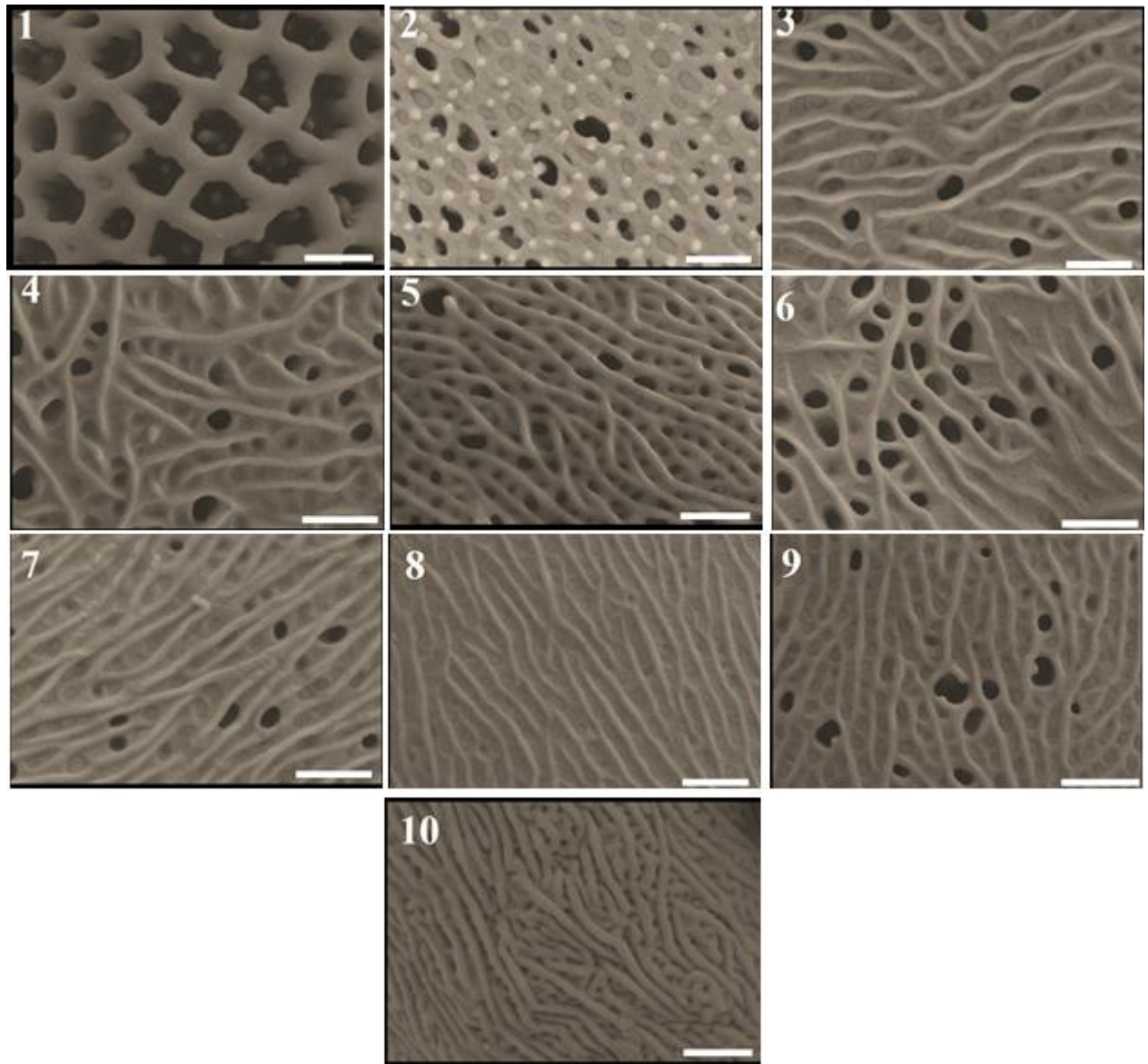


Figure 3. Pollen morphology of *Veronica* by scanning electron microscopy (Ornamentation). 1-*V. bozakmanii*, 2-*V. triphyllos*, 3-*V. persica*, 4-*V. triloba*, 5-*V. anagallis-aquatica*, 6-*V. oxicarpa*, 7-*V. cinerea*, 8-*V. macrostachya* subsp. *mardinensis*, 9-*V. orientalis* subsp. *orientalis*, 10-*V. orientalis* subsp. *nimrodi* (scale bar 1 μm)

4. Conclusions and discussion

The pollen morphology of the 10 taxa of *Veronica* genus included in Plantaginaceae was studied in detail using light microscope and SEM. Some authors have emphasized that there is a close relationship between Plantaginaceae and Scrophulariaceae [20; 21].

In the first studies conducted on the pollens of Plantaginaceae stenopalynous family, they have not associated pollen characteristics with the taxonomy of the family [22; 23]. Pollen grains of Plantaginaceae are generally characterized by having medium-sized or small, radial symmetry, apolar, polyaperturate (periporate) 4-15 apertures; being porate, spheroidal, prolate-spheroidal shaped; being with or without operculum, with or without annulus, having scabrate, verrucate, verrucate-granulate and areolate ornamentation without costa, and being anemophilous [24; 25; 26].

As a result of the study we conducted using light microscope, it was determined that the pollen grains of *Veronica* taxa had exine of 0.92-0.99 μm , intine of 0.36-0.51 μm , polar axis of 21.95-45.26 μm , equatorial axis of 15.61-35.58 μm , colpus length of 18.69-38.32 μm , and colpus width of 4.75-7.60 μm . As a result of the study we performed with SEM, it was found that the pollens of *Veronica* taxa had prolate, subprolate and prolate-spheroidal pollen shapes and their ornamentations were reticulate, striate-microreticulate and microecinate-perforate and their exine structure was tectate. Also, the lumina number in 1 μm^2 was 9 on average, the scabrate number in 1 μm^2 was 10.5 on average, the muri thickness was 0.23 μm in μm^2 , and the lumina diameter was 0.43 μm (Table 1 Figure 1-2-3).

İnceoğlu & Karamustafa [27] studied on 6 taxa of *Veronica* genus with Wodehouse and Erdtman methods. The pollen grains of *Veronica* genus are tricolpate, oblate-spheroidal and spheroidal and their exine ornamentation is granulate. The average values of the pollen size of the examined species were 33.3 x 33.7 µm according to Wodehouse. According to Erdtman, the average values were measured to be 32.8 x 24.2 µm. In the present study, only Wodehouse method was used. The average (P) was 32.4 µm and (E) was 24.7 µm. The pollens of *Veronica* genus were prolate, subprolate, prolate-spheroidal and their exine ornamentation was reticulate and striate-reticulate.

Martinez-Ortega et al. [28] studied 30 taxa of *Veronica* using light and scanning electron microscopes. Their pollen was averagely 30.8 µm (P) and 28.7 µm (E) and their pollen shapes are tricolpate and occasionally 2-4 colpate. Their ornamentation is rugulate-perforate or verrucate. Also, two types of ornamentation were determined: rugulate-reticulate and striate-microreticulate. The average values of the pollens of the common taxa (*V. triphyllos* L., *V. persica* Poir., *V. triloba* Opiz, *V. anagallis* subsp. *aquatica* L.) in the present study were 30 x 26.4 µm. The pollen shapes were tricolpate and unlike this study, their ornamentation was striate-reticulate.

Four species of *Veronica* genus were examined using light and scanning electron microscope [29]. In a previous study, the pollen type was found to be tricolpate in *V. persica* pollens, perprolate in *V. officinalis* L., subprolate in *V. multifida* L. and oblate-spheroidal in *V. beccabunga* L. In terms of size, the examined *Veronica* pollen had 27.38 x 19.40 µm on average. The sizes of the pollens varied between 16.7 x 13.3 µm in *V. multifida* L. and 39.5 x 19.5 µm in *V. persica* Poir. Operculum ornamentation was mostly rugulate-perforate in *V. multifida* L. and verrucate-perforate in *Veronica persica* Poir., *Veronica beccabunga* L. and *Veronica officinalis* L. species. Ornamentation were striate-reticulate and striate-microreticulate.

In the present study, the pollen size in *V. persica* was between 34.37 µm (P) and 22.78 µm (E) and the pollen type was found to be tricolpate and unlike this study, ornamentation was determined to be striate-reticulate. Martine-Ortega et al. [28] and Kaplan et al. [29] found that the taxonomic value of pollen characters in *Veronica* species examined by them was limited and remarkable and the differences between the pollen were not a very important character for the taxonomy of this genus and stated that striate-reticulate ornamentation was the most frequent ornamentation in *Veronica*.

Studies have been conducted to demonstrate and assess the taxonomic importance of the palynological characteristics of 6 genera and 9 species of Scrophulariaceae [30]. The equatorial and polar axis sizes of the pollens in *V. anagallis-aquatica* L. species are 25 µm and 21 µm on average, respectively and their pollen shape are sub-prolate. The pollen size in *V. melissifolia* Poir. species is 34.5 x 25 µm on average and their pollen shape is prolate. The pollen size in *V. persica* is 25.83 x 27.5 µm and their pollen shape is oblate-spheroidal. In the present study, the pollen size of *V. anagallis-aquatica* L. was 27.65 x 22.02 µm and their pollen shape was sub-prolate and their ornamentation was striate-reticulate and it had similarity with this study. The pollen size in *V. persica* was 34.37 x 22.78 µm and we found the pollen shape to be prolate unlike this study.

In the study conducted by El-Amier [31] in 25 species of different genera, it was observed that the apertures of the researched pollens were mostly colporate, colpate, porate and rarely inaperturate. *V. anagallis-aquatica*, one of the studied species, was determined to be tricolporate and subprolate. In the present study, the pollen of *V. anagallis-aquatica* L. species was tricolporate, its exine ornamentation was striate-reticulate and its pollen shape was subprolate and it was different from this study.

Yaylacı et al. [32] performed measurements with the published species (*V. ersin-yucelii* Yaylacı, O. Koyuncu & Ocak) *V. caespitosa* Boiss. and *V. multifida* L. species using Wodehouse and Erdtman Methods and they compared them. As a result, the pollens of these species had radial symmetry, was isopolar, prolate-subprolate and tricolpate, operculum was rugulate-perforate and the ornamentation was striate-reticulate.

It was determined that the data obtained on *Veronica* genus was compatible with the previous studies and the pollen shapes of this species were prolate and subprolate, exine was 0.92-0.98 µm, exine ornamentation was reticulate and striate-reticulate, and its size was averagely 32.42 µm (P) and 24.73 µm (E).

A study was conducted on the pollen morphology of 25 taxa of *Veronica* genus included in Plantaginaceae family. As a result of the study, the pollen size was measured to be averagely 10-25 µm in two species (*V. alpina* L., *V. arvensis* L.) and averagely 26-50 µm on average in the other species. The ornamentation was observed to be microreticulate in *V. allionii* Vill., *V. anagallis-aquatica*, *V. barrelieri* H.Schott ex Roem. & Schult., *V. spicata* L. species; striate-perforate in *V. cinerea* Boiss. & Balansa, microgemmate and perforate in *V. hederifolia* L. species, microreticulate and microechinate in *V. praecox* species, microechinate and perforate in *V. sublobata* M.A.Fisch. and *V. triloba* Opiz species and striate-microreticulate in the other species [33]. In the present study, the pollen sizes of the common species (*V. anagallis-aquatica* L., *V. cinerea* Boiss. & Balansa, *V. persica* Poir., *V. triloba* Opiz) were 33.88-25.41 µm and their ornamentation was observed to be striate-reticulate. While the ornamentation of *V. triloba* species in the present study was striate-reticulate, it was observed to be microechinate and perforate in this study.

In this study, morphological characteristics of pollen of 10 taxa belonging to *Veronica* L. (Plantaginaceae) genus were determined.

Acknowledgements

The authors thank to Assoc. Prof. Dr. Rıza BİNİZET who is helper to take of electron photographs of pollen surface.

References

- [1] Christenhusz, M.J.M., Byng J.W. (2016). The number of known plants species in the world and its annual increase. *Phytotaxa* 261 (3): 201–217. DOI: <http://dx.doi.org/10.11646/phytotaxa.261.3.1>
- [2] Albach, D.C., Martínez-Ortega, M.M., Delgado, L., Weiss-Schneeweiss H., Özgökçe F., Fischer, M.A. (2008). Chromosome numbers in Veroniceae: review and several new counts. *Annals of the Missouri Botanical Garden* 95: 543–566. <https://doi.org/10.3417/2006094>.
- [3] Albach, D.C., Meudt, H.M., Oxelman, B. (2005a). Piecing together the “new” Plantaginaceae. *American Journal of Botany*, 92 (2): 297–315.
- [4] Judd, W.S., Campbell, C.S., Kellogg, E.A., SKEVENS, P.E. (1999). *Plant Systematics, A phylogenetic Approach*. USA: *Sinauer Associates Inc.*, 373-375.
- [5] APG (2016) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. *Botanical Journal of the Linnean Society* 181: 1–20. <https://doi.org/10.1111/boj.12385>
- [6] Fischer, M.A. (1978). *Veronica L.* In: Davis, P.H. (Ed.) *Flora of Turkey and the East Aegean Islands*. Edinburgh University Press, Edinburgh, 6: 689–753.
- [7] Davis, P.H., Mill, R.R., Tan, K. (Eds.). (1988). *Flora of Turkey and the East Aegean Islands (Supplement)*. Vol. 10. Edinburgh University Press, Edinburgh.
- [8] Ekim, T. (2000). *Veronica L.* In: Güner A., Özhatay N., Ekim T. & Başer K.H.C. (Eds.) *Flora of Turkey and the East Aegean Islands (Supplement II)*. Edinburgh University Press, Edinburgh, 11: 194–196.
- [9] Öztürk, F., Öztürk, A. (2000). A8, B7, B9, B10, C10 Coğrafik Kareleri ve Türkiye için *Veronica L.* (Scrophulariaceae) Cinsine Ait Yeni Floristik Kayıtlar. *Y.Y.Ü. Fen Bilimleri Enstitüsü Dergisi*, 6: 25-28,
- [10] Öztürk A. 2001. Two new species of *Veronica L.* (Scrophulariaceae) from Turkey, *V. vanensis* and *V. yildirimlii*. *The Herb Journal of Systematic Botany*, 8 (1): 5–8.
- [11] Vural, C., Özcan, S., Akbulut, M. (2009). New combination in *Veronica* (Scrophulariaceae s.l.) based on morphological characters and the seed storage protein polymorphism. *Journal of Systematics and Evolution*, 47 (2): 168–172. DOI: 10.1111/j.1759-6831.2009.00016.x
- [12] Risch, C. (1939). Die Pollenkörner der in Deutschland wild wachsenden Scrophulariaceen. *Ver. Dtsch. Bot. Ges.*, 57, 108–121.
- [13] Huang, T.C. (1972). *Pollen flora of Taiwan*. Taipei: Bot. Dept. Natl. Taiwan Univ. Press.
- [14] Hong, D.Y., Nilsson, S. (1983). On the validity of the genus *Cochlidiosperma* Reichenb. (Scrophulariaceae), as supported by additional palynological evidence. *Acta Phytotax Sin.*, 21: 146–150.
- [15] Hong, D.Y. (1984). Taxonomy and evolution of the Veroniceae (Scrophulariaceae) with special reference to palynology. *Opera Bot.*, 75:5-60.
- [16] Fernández, I., Juan, R. & Pastor, J. (1997). Morfología polínica de *Veronica L.* (Scrophulariaceae) en el suroeste de España. – *Acta. Bot. Malacit.* 22: 65 –72.
- [17] Saeidi-Mehrvarz, S., & Zarrei, H. (2006). Pollen morphology of some species of the genus *Veronica* (Scrophulariaceae) in Iran. *Wulfenia*, 13, 1–10.
- [18] Wodehouse, R.P. (1935). *Pollen Grains*. McGraw-Hill Book Company, New York, 574 pp.
- [19] Hesse, M., Halbritter, H., Zetter, R., Weber, M., Buchner R., Frosch-Radivo, A., Ulrich, S. (2009). *Pollen Terminology, An illustrated handbook*. 15-23. Springer-Verlag/Wien, Austria. DOI:10.1007/978-3-211-79894-2
- [20] Heywood, V.H. (1993). *Flowering plants of the world*, Oxford: Andromeda, Ltd. 1- 241
- [21] Mabberley, D.J. (1997). *The plant-book, a portable dictionary of the vascular plants*. 2nd Ed. p. 564, Cambridge: Cambridge University Press.
- [22] Erdtman, G. (1952). *Pollen Morphology and Plant Taxonomy*. Angiosperms. Chronica Botanica Co.,
- [23] Kupriyanova, L.A. & Alyoshina, L.A. (1978). Pollen dicotyledonearum Florae Partis Europaeae. URSS. Lamiaceae-Zygophyllaceae. (in Russian). Nauka 184 p. Komarov Botanical Institute of Russian Academy of Sciences.
- [24] Perveen, A. & Qaiser, M. (2004). Pollen flora of Pakistan. -XXXVIII. Plantaginaceae. *Pak. J. Bot.*, 36 (1): 19-25.
- [25] Al-Quran, S.A. (2004). Pollen Morphology of Plantaginaceae in Jordan. *Pakistan Journal of Biological Sciences*, 7 (9): 1594-1602.
- [26] Bukhari, N.A.W. (2009). Pollen Morphology of some *Plantago* species native to Saudi Arabia and their taxonomic implication. *BioDiCon*, 2/3, 2009. 1-6.

- [27] İnceođlu, Ö. & Karamustafa, F. (1977). The Pollen Morphology of Plants in Ankara Region V. Plantaginaceae. Communications, Series C2: *Botanique Tome*, 21: 145-149.
- [28] Martinez-Ortega, M.M., Sanchez J.S., Rico E. (2009). Agudo J. A. S. Pollen morphology in the genus *Veronica* L. (Plantaginaceae) and its systematic significance. *Grana*; 48: 239–257. <https://doi.org/10.1080/00173130903364723>
- [29] Kaplan, A., Hasanođlu, A., & İnce, İ.A. (2007). Morphological, Anatomical and Palynological Properties of some Turkish *Veronica* L. Species (Scrophulariaceae). *International Journal of Botany*, 3 (1): 23-32. DOI: 10.3923/ijb.2007.23.32
- [30] Asmat, T., Khan, M.J., Ahmed, M., Zafar, M., Manzoor, F., Munir, M. ... Abbasi, S.N. (2011). Pollen morphology of selected species of Scrophulariaceae of District Dir Upper, Pakistan. *Journal of Medicinal Plants Research*, 5(28): 6423-6428. DOI: 10.5897/JMPR11.723
- [31] El- Amier, Y.A. (2015). Morphological studies of the pollen grains for some hydrophytes in coastal Mediterranean lakes, Egypt. *Egyptian Journal of Basic and Applied Sciences*, 2:132 -138. <https://doi.org/10.1016/j.ejbas.2015.04.001>
- [32] Yaylacı, Ö.K., Sezer, O., Özgışi, K., Öztürk, D., Erkara, İ.P., Koyuncu, O. & Ocak, A. (2018). A new *Veronica* (Plantaginaceae) species from Central Anatolia, Turkey. *Phytotaxa* 362 (1): 055–067. DOI: <http://dx.doi.org/10.11646/phytotaxa.362.1.4>
- [33] Anonim, (2019). <https://www.palдат.org/search/genus/Veronica>. (Erişim Tarihi: 07.10.2019).