*Turczaninowia* 27, 1: 151–170 (2024)
*DOI: 10.14258/turczaninowia.27.1.18*
http://turczaninowia.asu.ru

ISSN 1560–7259 (print edition)
**TURCZANINOWIA**
ISSN 1560–7267 (online edition)

УДК 582.912.46(560)

# Contribution to the biosystematics of the wild *Vaccinium* species distributed in Turkey

G. Yılmaz[1, 3*], K. Coşkunçelebi[1, 4], M. E. Güzel[1, 5], S. Makbul[2, 6]

[1] *Karadeniz Technical University, Department of Biology, Kanuni Campus, Ortahisar, Trabzon, 61080, Turkey*

[2] *Recep Tayyip Erdogan University, Zihni Derin Campus – Fener Mahallesi, Rize, 53100, Turkey*

[3] *E-mail: gulsahyilmaz@ktu.edu.tr; ORCİD iD: https://orcid.org/0000-0002-1806-2344*

[4] *E-mail:kamil@ktu.edu.tr; ORCİD iD https://orcid.org/0000-0001-5713-6628*

[5] *E-mail: muraterdemguzel@hotmail.com; ORCİD iD http://orcid.org/0000-0002-7923-7443*

[6] *E-mail: serdar.makbul@erdogan.edu.tr; ORCİD iD http://orcid.org/0000-0001-8798-0926*

* *Corresponding author*

***Keywords***: Ericaceae, fruit, leaf, pollen grain, seed.

***Summary***. The genus *Vaccinium* L. (Ericaceae) consists of shrubs or dwarf shrubs species widely distributed in Southeast Asia, America, and Europe. In the present paper, members of the genus (*V. arctostaphylos*, *V. myrtillus*, *V. uliginosum, V. vitis-idaea*) naturally grown in Northeast Anatolia were compared in terms of leaf venation, seed micromorphology, and palynological properties based on 16 populations in detail. Present findings revealed that number of areoles (the small area bounded by secondary veinlet) is 8–9 for *V. arctostaphylos,* 5–7 for *V. myrtillus*, 3–4 for *V. uliginosum* and *V. vitis-idaea.* Scanning electron microscope observation shows that the leaf adaxial surface is fiber-fluted in *V. arctostaphylos*, ruminate in *V. myrtillus*, *V. uliginosum*, and *V. vitis-idaea* due to epicuticular waxes. In addition, the seed shape of *V. arctostaphylos* in outline varies from triangular, tetragonal to oval, whereas they are lunate to reniform or falcate in the rest of the examined taxa. Epidermal cells of the seed are quadrilateral with straight anticlinal walls in *V. arctostaphylos*, however, they are most elongate rectangle with weakly undulate anticlinal walls in the rest species. The mean tetrad diameter (D) of pollen belonging to all examined species is 29.89 (21.47–43.22) μm while the lowest mean D was found in *V. uliginosum* (24.59 μm) and the highest mean D was found in *V. arctostaphylos* (36.74 μm). Principal component analysis based on 47 traits (flower: 9, leaf: 18, seed and fruit: 9 and pollen: 11) showed that the leaf length and width, teeth numbers, tetrad diameter, equatorial axis, and polar axis were the most valuable characters to distinguish the examined taxa in the present paper.

# К биосистематике диких видов *Vaccinium*, распространенных в Турции

Г. Илмаз[1*], К. Джошкунчелеби[1], М. Э. Гюзель[1], С. Макбул[2]

[1] *Черноморский технический университет, г. Трабзон, 61080, Турция*

[2] *Университет им. Реджепа Тайипа Эрдогана, Кампус Зихни Дерин – Фенер Махаллеси, г. Ризе, 53100, Турция*

***Ключевые слова***: вересковые, лист, плод, пыльцевое зерно, семя.

***Аннотация***. Род *Vaccinium* L. (Ericaceae) состоит из кустарниковых и кустарничковых видов, широко распространенных в Азии (гл. обр. Юго-Восточной), Америке и Европе. В настоящем исследовании было прове-

*Поступило в редакцию 12.10.2022*
*Принято к публикации 06.05.2024*

*Submitted 12.10.2022*
*Accepted 06.05.2024*

дено сравнительное изучение жилкования листьев, микроморфологии семян и палинологических особенностей 16 популяций четырёх представителей *Vaccinium* (*V. arctostaphylos, V. myrtillus, V. uliginosum, V. vitis-idaea*), естественно произрастающих в Северо-Восточной Анатолии. Полученные результаты показали, что для *V. arctostaphylos* характерно наличие 8–9 ареол, для *V. myrtillus* – 5–7, для *V. uliginosum* и *V. vitis-idaea* – 3–4 ареолы, образованные вторичной жилкой. Данные СЭМ показали, что адаксиальная поверхность листа у *V. arctostaphylos* покрыта волокнистыми бороздками, у *V. myrtillus*, *V. uliginosum* и *V. vitis-idaea* она рифленая из-за эпикутикулярных восков. Кроме того, форма семян *V. arctostaphylos* варьирует от треугольной и четырехугольной до овальной, в то время как у остальных исследованных таксонов она лунообразная, почковидная или серповидная. Эпидермальные клетки семени четырехугольные, с прямыми антиклинальными стенками у *V. arctostaphylos*, однако у остальных видов представляют собой вытянутый прямоугольник со слабоволнистыми антиклинальными стенками. Средний диаметр тетрады (D) пыльцы всех исследованных видов составляет 29,89 (21,47–43,22) мкм, наименьший у *V. uliginosum* (24,59 мкм), а наибольший – у *V. arctostaphylos* (36,74 мкм). Анализ основных компонент, основанный на 47 признаках (9 признаков цветка, 18 – листа, 9 – семени и плода и 11 – пыльцы), показал, что длина, ширина и число зубцов листа, диаметр тетрады, экваториальная ось и полярная длина пыльцевых зерен являются наиболее ценными признаками для разграничения исследованных видов.

## Introduction

The genus *Vaccinium* L., the third largest genus in Ericaceae, contains approximately 450 species worldwide (Cronquist, 1981). The genus is mostly distributed in Southeast Asia, America and Europe including subtropical or tropical montane regions on most continents (Vander Kloet, 1988). Members of *Vaccinium* have been subjected to several taxonomical studies on both regional and global scale up to now. Sleumer (1941) reported that the inflorescence type, calyx tube shape, corolla shape, and type of stamen appendages are valuable taxonomical traits for the members of *Vaccinium*. Likewise, Palser (1961) confirmed the sectional classification for *Vaccinium* taxa distributed in the United States mainly based on the floral structure. However, according to Stevens (1971), many floral characters like calyx shape, corolla shape, and stamen supply limited information to distinguish taxa within the genus *Vaccinium*. On the other hand, Nekrasova (1952) emphasized that leaf indumentum is valuable to distinguish *Vaccinium* members in the "Flora of the USSR". However, it is reported that the vegetative characters are much less important than floral characters in circumscribing sections in the genus (Odell, Vander Kloet, 1991). Schultz (1944) reported that the only difference between *V. scoparium* Leiberg ex Coville and *V. myrtillus* L. is berry color at a lower elevation. Both puberulent and glabrous twigs may occur in both taxa (often on the same plant) and puberulent twigs are not restricted to *V. myrtillus*. Fang and Stevens (2005) used leaf venation and fruit size to distinguish *V. myrtillus, V. uliginosum* L., and *V. vitis-idaea* L. as key characters in the "Flora of China". It is well known that the carpological investigation provides large number of diagnostic features for the classification of taxa at several level (Szkudlarz, 1999b) however there are limited carpological studies related to members of *Vaccinium* at a specific level (Vander Kloet, 1988; Szkudlarz, 1999a, 2001).

The genus *Vaccinium* is known to have a basic chromosome number of $x = 12$ (Darrow et al., 1944). Although diploid chromosome numbers are common in the genus, several polyploidy cytotypes were also recorded in *V. uliginosum*, *V. arctostaphylos* L., and *V. myrtillus* (Hagerup, 1928; Darrow et al., 1944). However, there seems to be no correlation between morphological characters and ploidy level (Young, 1970; Vander Kloet, 1988).

Sarwar et al. (2006) evaluated palynological features of 37 *Vaccinium* species in detail and reported that palynological characters are not in accordance with the current infrageneric classification, but they provide useful information to figure out the taxonomic problem within the genus. Goldy et al. (1984) also reported that the exine sculpture contributes to the delimitation of *Vaccinium* taxa. According to Cockerham and Galletta (1976), tetrad diameter was calculated 11 % larger in the tetraploid pollen than diploid pollen in the genus *Vaccinium*. Similarly, slight differences in tetrad size and exine sculpture were recorded between the New World blueberry species and Old World blueberry species by Sarwar et al. (2006). The smallest pollen grains were also found in *V. uliginosum* by Sarwar and Takahashi (2007).

The most recent and widely used molecular phylogenetic data also improved our knowledge of the taxonomy of *Vaccinium*. Firstly, Sleumer (1941) revealed the polyphyletic origin of the genus. However, the most comprehensive phylogenetic studies on the genus at sectional level (sect.

*Macropelma* Klotzsch and sect. *Myrtillus* Dumortier and sect. *Hemimyrtillus* Sleumer) and on the tribe *Vaccinieae* Rchb. were performed by Powell and Kron (2002) and Kron et al. (2002), respectively. The latter two molecular studies also revealed that *Vaccinium* is a polyphyletic genus as previously reported by Sleumer (1941). *Vaccinium arctostaphylos* is placed within a clade sister to *V. uliginosum* (Powell, Kron, 2002). Correspondingly, Sultana et al. (2020) reported that *V. myrtillus* and *V. macrocarpon* Ait. are closely related species and formed a sister clade. Kron et al. (2002) suggested that more morphological and molecular data are necessary to recognize members of *Vaccinium* within the tribe *Vaccinieae*. Despite many advantages of phylogenetic works, the representation of the *Vaccinium* in phylogenetic studies is still too limited to draw taxonomic conclusions, so Pedraza-Penalosa and Luteyn (2011) described seven new species based on traditional circumscription from Andean South America.

The first comprehensive taxonomic study on the Turkish native species of *Vaccinium* (*V. arctostaphylos*, *V. myrtillus*, *V. uliginosum*, and *V. vitis-idaea*) was presented by Stevens (1978). Afterward, the systematics of the Turkish *Vaccinium* was updated by Terzioğlu (2012) in the checklist of the "Flora of Turkey" without any further taxonomic contributions. Subsequently, many researchers mostly focused on chemical properties of the Turkish *Vaccinium*. Ayaz et al. (2001) firstly examined the levels of fructose and glucose in *V. arctostaphylos* and *V. myrtillus* at three different maturity stages in NE Turkey. Similarly, anthocyanin and antioxidant contents in the berries of two species were reported from Turkey (Çolak et al., 2016). Furthermore, altitude variation in the volatile composition of blueberry species (*V. arctostaphlyos*, *V. uliginosum*, *V. vitis-idaea*, and *V. myrtillus*) distributed in the NE Anatolia was examined by Erik et al. (2020). Some phenological characteristics and distribution patterns of the Turkish *Vaccinium* were compiled from accessible sources by Çelik and Serçe (2015).

In the present paper, we aimed to explore surface and venation patterns of leaf, seed macro-micromorphology, and pollen features of the *Vaccinium* species distributed in NE Anatolia, contribute filling the gaps in the biosystematics features of the examined taxa and determine valuable characters to distinguish the examined *Vaccinium* species.

## Materials and methods

### Specimens

Samples for biosystematic studies were collected from sixteen populations of *V. arctostaphlyos*, *V. uliginosum*, *V. vitis-idaea*, and *V. myrtillus* in Turkey within the scope of the MSc thesis of the first author

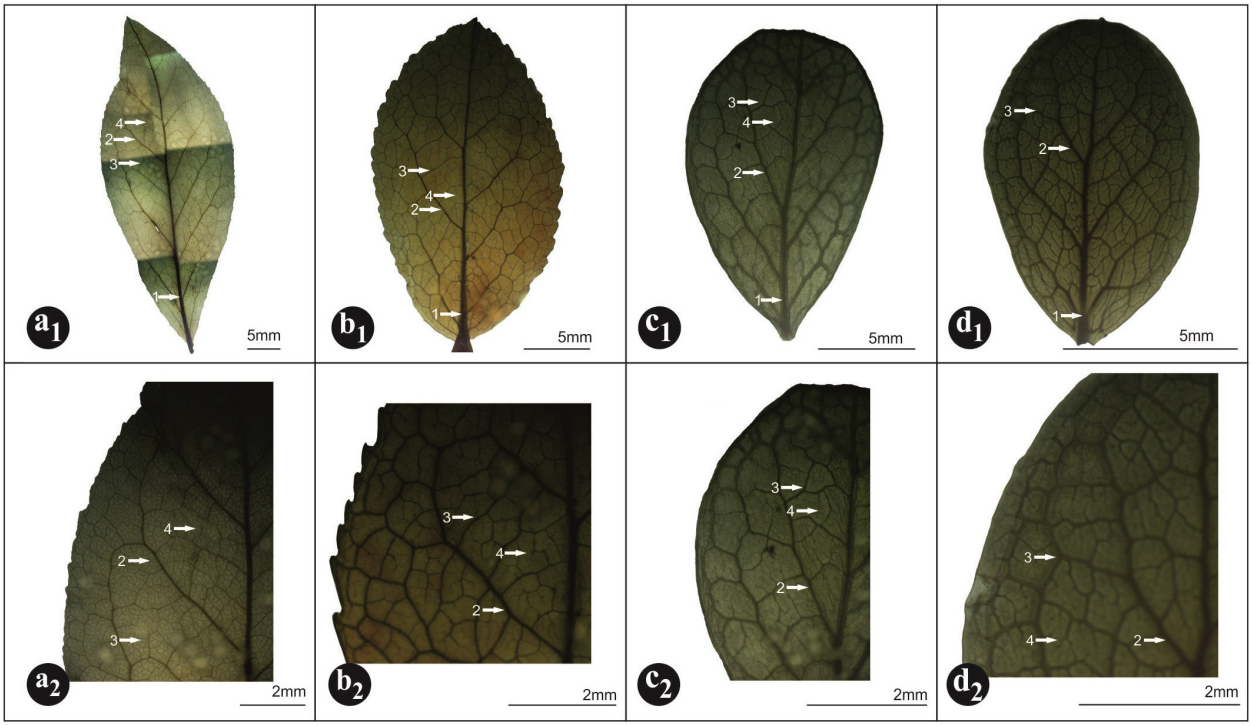


Fig. 1. Leaf areolar (vein islets) pattern: $a_{1-2}$ – *Vaccinium arctostaphylos*; $b_{1-2}$ – *V. myrtillus*; $c_{1-2}$ – *V. uliginosum*; $d_{1-2}$ – *V. vitis-idaea*. Arrow shows the primary (1), secondary (2), tertiary (3), and quaternary veins (4).

(Table 1). The specimens were labeled, numbered, annotated with the date of collections, the locality and the name of the collector during the field studies. After identification of the samples according to Stevens (1978), all vouchers were stored in the herbarium of the Department of Biology at Karadeniz Technical University (KTUB). Additionally, healthy leaves and fruits including seeds for morphological studies and flowers for palynological studies were also collected from the same population during the field trips. Taxonomic names followed Terzioğlu (2012), and distribution details were given according to the Turkey Grid System (Davis, 1965).

**Protocols for leaf venation studies**

At least 3–4 entire mature leaves from each investigated population of the Turkish *Vaccinium* were immersed in 2.5 % Sodium Hydroxide for 15–20 days (Panda, Kırtania, 2016). After that, all leaves were rinsed with distilled water and then stained with safranin for 15 minutes (Vardar, 1962). After staining, all leaves were again rinsed with distilled water before taking photos with a Leica DFC 490 digital camera attached to a stereomicroscope. Areoles number (the area bounded by veins) and divergence angle of secondary, tertiary, and quaternary veins were calculated from at least 3–4 different part

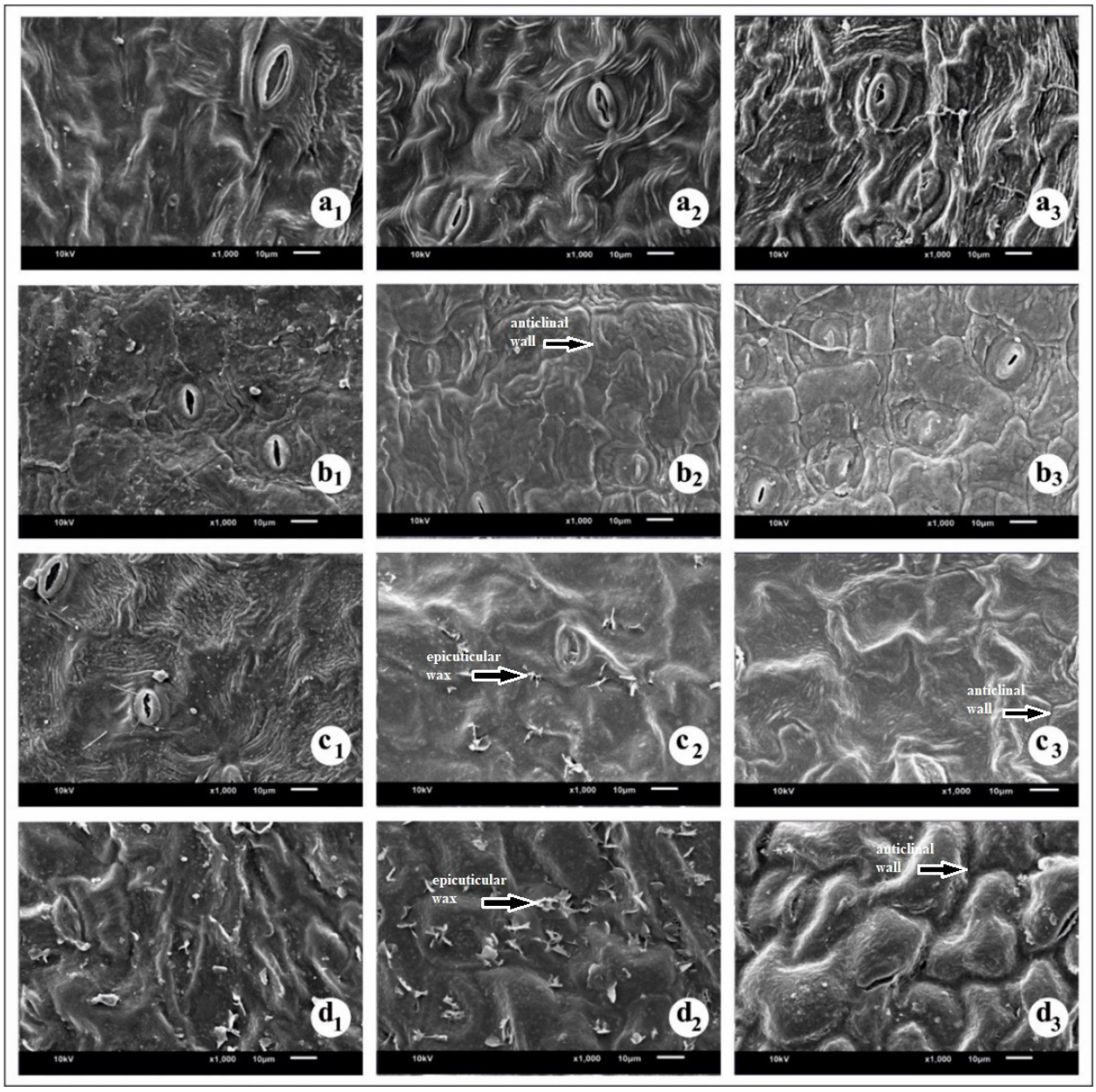


Fig. 2. Adaxial leaf surface, scanning electron microscope: $a_{1-3}$ – *Vaccinium arctostaphylos*; $b_{1-3}$ – *V. myrtillus*; $c_{1-3}$ – *V. uliginosum*; $d_{1-3}$ – *V. vitis-idaea.*

of each stained leaves belonging to each investigated population according to Saibaba and Rao (1990) and Panda and Kirtania (2016).

**Protocols for leaf micromorphology studies**

Firstly at least three pieces of dried leaves about 1 $cm^2$ belong to each investigated population were cut out from the middle part by a razor blade and then all pieces were transferred onto aluminum stubs, coated with gold in a sputter-coater and examined under the JEOL-JSM 6610 scanning electron microscope (SEM) at the Central Research Laboratory of Recep Tayyip Erdogan University at a voltage 10 kV. All micrographs were taken 200× and 1000× magnification. At least ten leaf micrographs taken 200× and 1000× magnification per investigated population was observed for micromorphological description. The terminology of Simpson (2012) and Stearn (1985) was adopted for the leaf micromorphological descriptions.

**Protocols for seed macro and micromorphology studies**

A total of 12 dried fruits from each investigated population were boiled in water and then all seeds were extracted from fruits. Then, the seeds were stored in anhydride-sulfuric acid (9 : 1) for 24 hour at room temperature. After that, all seeds were rinsed with distilled water, dried in oven at 50 °C for 24 hour and photographed by a Leica DFC 490


Fig. 3. Seed morphology, light microscope: a – *Vaccinium arctostaphylos*; b – *V. myrtillus*; c – *V. uliginosum*; d – *V. vitis-idaea*.

stereomicroscope attached to a digital camera. Dried seeds also were transferred on aluminum stubs with double-sided adhesive carbon tape and coated with gold for 4 min in a sputter-coater for SEM studies. Seed micrographs were observed by a JEOL-JSM 6610 microscope at the Central Research Laboratory of Recep Tayyip Erdogan University at 50×, 300×, 1000×, and 2000× magnification. The terminology of Barthlott (1981), Stearn (1985), Coşkunçelebi et al. (2000, 2016) and Khorasani et al. (2020) was mainly followed for the seed macro-micromorphological descriptions. Qualitative characters of seed were described according to terminology provided by Khorasani et al. (2020).

**Protocols for palynological studies**

Several randomly selected flowers were collected from each population belonging to investigated species. Pollen grains were extracted from the flower according to the acetolysed method proposed by Erdtman (1952) and then one half was immersed in an alcohol solution of glycerine (for LM) to obtain permanent slides and the other in ethyl alcohol 96 % (for SEM). Permanent slides were examined using Leica S6D light microscope to measure or determine the following parameters: Tetrad axis (D), equatorial axis (E or d), polar axis (P), P/E ratio, D/d ratio, colpus length (2f), colpus width (W), septum (total exine) thickness (Se), exine (Ex), 2f/W ratio, 2f/D ratio. For each analyzed population, thirty mature and correctly formed pollen grains were measured by light microscopy. For SEM studies, air-dried acetolysed pollen grains were transferred onto aluminum stubs and coated with gold for 4 min in a sputter-coater and examined by a JEOL-JSM 6610 microscope at the Central Research Laboratory of Recep Tayyip Erdogan University at a voltage 10 kV. Pollen photographs and micrographs were taken using Leica S6D light microscope and JEOL-JSM 6610 electron microscope, respectively. For the pollen grains, the description terminology of Sarwar (2007), Punt et al. (2007) and Park and Song (2010) were mainly followed.

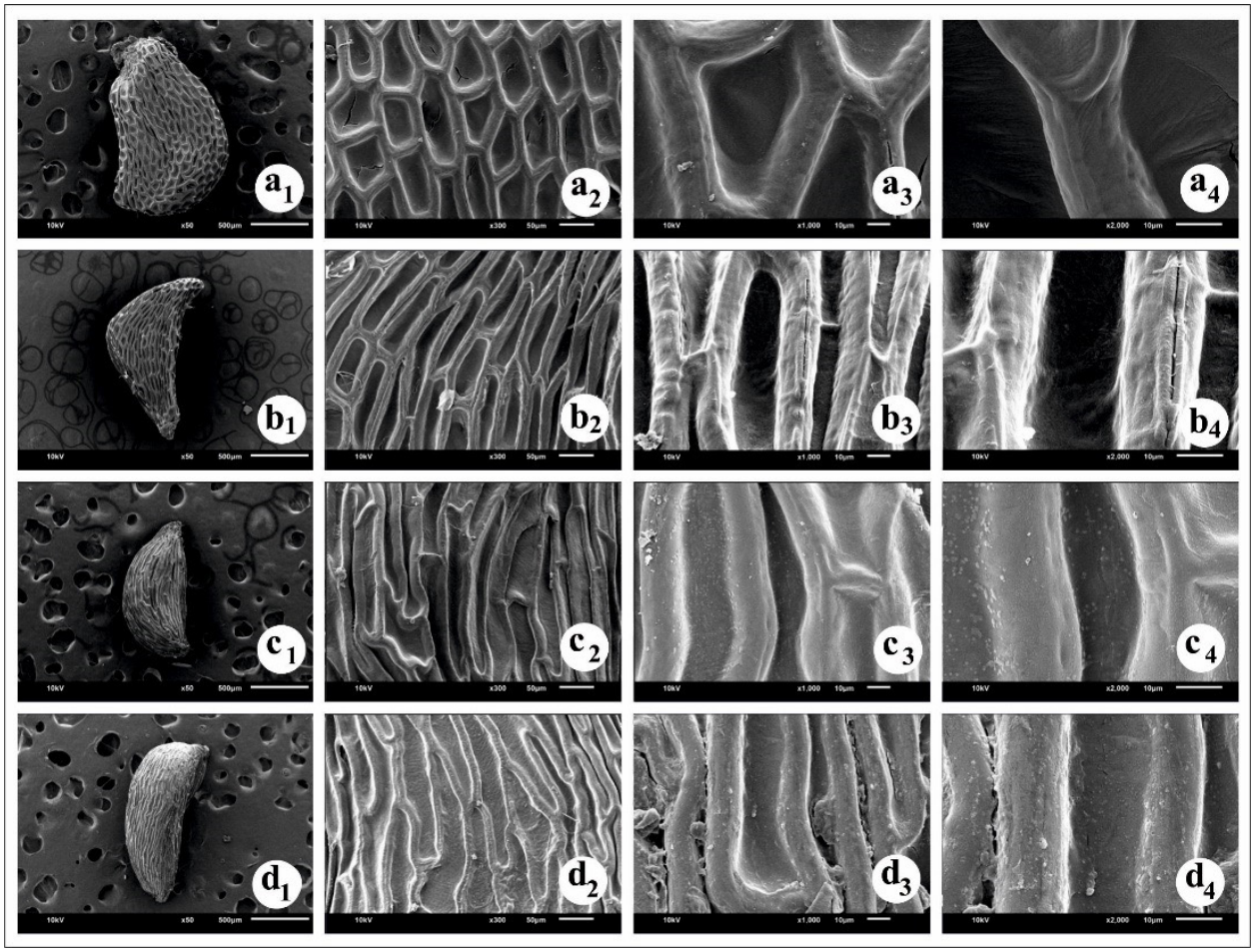


Fig. 4. Seed morphology, scanning electron microscope: $a_{1-4}$ – *Vaccinium arctostaphylos*; $b_{1-4}$ – *V. myrtillus*; $c_{1-4}$ – *V. uliginosum*; $d_{1-4}$ – *V. vitis-idaea.*

**Numerical analysis**

Forty-seven traits (Table 2) related to leaf, flower, fruit, seed and pollen grains were measured or scored using a light microscope. All scores or measurements were checked at least three or four times for each population. Average values and standard deviations (SD) of the all traits were given in Table 4 for each population. A data matrix including scores of 47 traits was subjected to cluster analysis (CA) and principal component analysis (PCA). For CA, a pair-wise matrix of resemblance values was calculated from the standardized data matrix, using Gower's coefficient of resemblance designed for mixed data sets (Sneath, Sokal, 1973). For PCA, the standardized data were used to create a covariance matrix. Five eigenvectors were extracted, providing axis onto which the standardized data were projected to give a two-dimensional plot of the examined taxa. All analyses were performed using MVSP computer programs for multivariate data analysis in ecology and systematics (Kovach, 2007).

## Results

**Traits of leaf, seed and pollen grains**

Findings related to leaf (shape, margins, and venation), seed, and pollen grains of each investigated taxon were given alphabetically in the following.

***Vaccinium arctostaphylos*** L. 1753, Sp. Pl. 351

***Leaf***: Elliptic-broadly lanceolate with serrate or serrulate margin in shape (Fig. $1a_1$). The secondary veins are opposite at the base of a primary vein and then alternatively arranged with a divergence angle of 25°–45° towards the primary vein tip and free-ending. The numbers of areoles formed by the secondary, tertiary, and quaternary veins are 8–9, 5–6 and 3–6, respectively (Fig. $1a_2$). The leaf adaxial surface under SEM is weakly striate; the epidermal cell borders are hardly indistinct (Fig. $2a_{1-3}$).

***Seed:*** Seeds are 1.3–1.5 mm length, brown, triangular, tetragonal or oval (Fig. 3a). Epidermal cells of seed coat are mostly polygonal in outline,

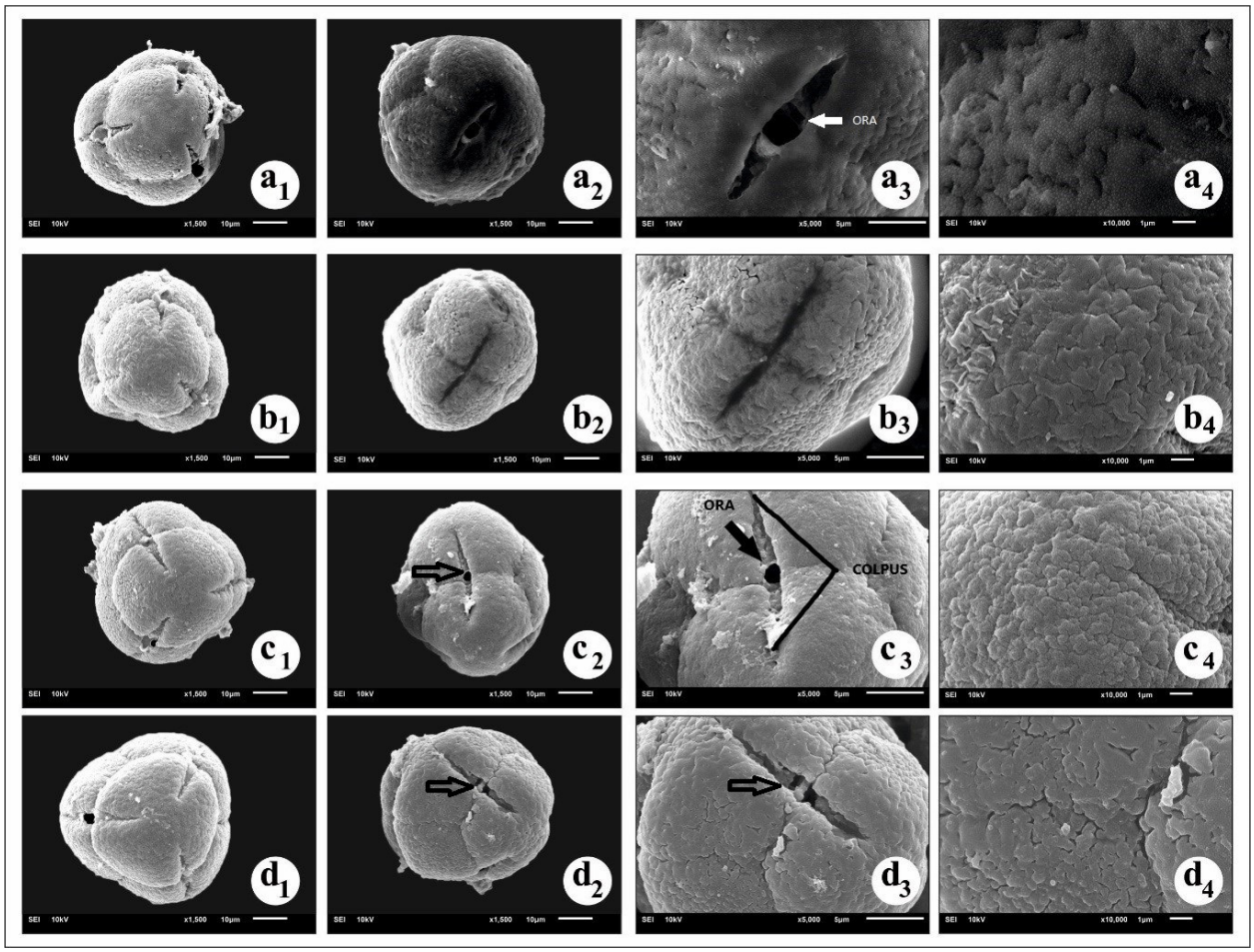


Fig. 5. Pollen morphology, scanning electron microscope: $a_{1-4}$ – *Vaccinium arctostaphylos*; $b_{1-4}$ – *V. myrtillus*; $c_{1-4}$ – *V. uliginosum*; $d_{1-4}$ – *V. vitis-idaea*.

anticlinal walls straight, raised, smooth, strongly thickened, periclinal cell walls smooth and concave (Fig. 4a$_{1-4}$).

***Pollen grains:*** Pollen grains are in tetrahedral tetrads, tetrad axis (D) 28.55–43.22 (36.7) µm, oblate-spheroidal, equatorial diameter (E or d) 22.34–31.02 (29.86) µm, polar axis (P) 15.15–23.99 (20.58) µm, P/E ratio 0.63–0.94 (0.81) µm, D/d ratio 1.27–1.38 (1.34) µm. Colpus is narrowing, colpus margin distinct. Ora is in the middle of the colpus, length (2f) 17.45–24.23 (21.95) µm, width (W) 1.98–3.65 (2.69) µm. Septum thickness (Se) 1.22–1.89 (1.46) µm thick, exine (Ex) 1.52–1.9 (1.72) µm thick (Fig. 5a$_4$). 2f/W ratio 9.04–9.45 (9.16) µm, 2f/D ratio 0.33–0.62 (0.47). Pollen grains are verrucate, microgranulate in the population of VA1, regulate in the rest examined populations. Representative micrographs of pollen under the SEM are given in Fig. 5a$_{1-4}$.

***Vaccinium myrtillus*** L. 1753, Sp. Pl. 349

***Leaf:*** Broadly elliptic or ovate, sharply serrate margin in shape (Fig. 1b$_1$). The secondary veins are alternatively arranged with a divergence angle of 30–55° toward a primary vein tip and free-ending. The numbers of areoles formed by the secondary, tertiary, and quaternary veins are 5–7, 5–9, and 3–6, respectively (Fig. 1b$_2$). The leaf adaxial surface under SEM is without striate; epidermal cell borders are slightly visible (Fig. 2b$_{1-3}$).

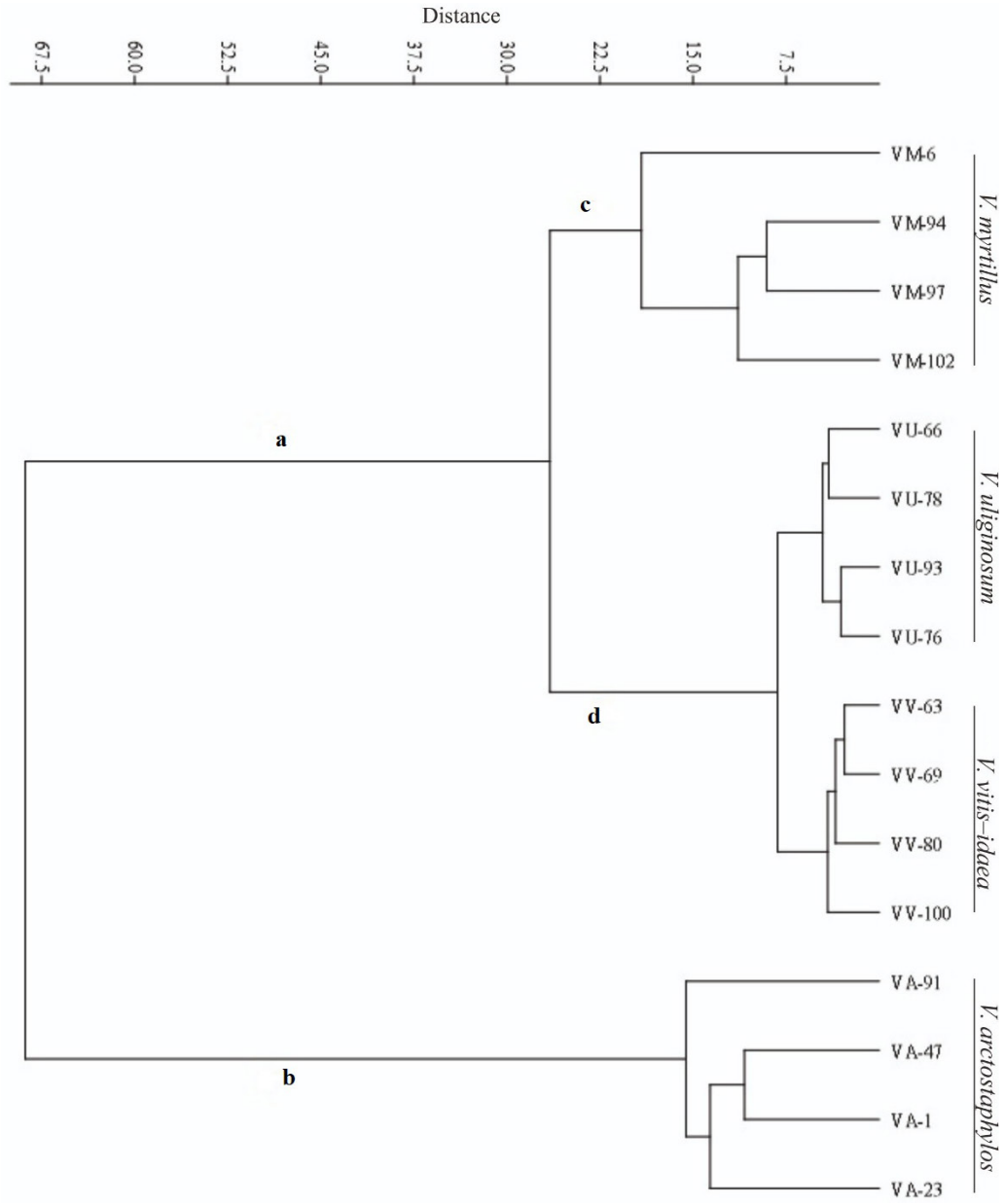


Fig. 6. UPGMA dendrogram of *Vaccinium* taxa based on morphological data (Details of the population numbers are given in Table 1).

***Seed:*** Seeds are 1.2–1.3 mm length, light or dark brown, lunate to reniform in outline (Fig. 3b). Epidermal cells of seed coat are elongated, mostly rectangle in shape, anticlinal walls straight, raised, slightly striated, thickened, the surface of outer periclinal cell wall is smooth and concave (Fig. 4b$_{1-4}$).

***Pollen grains:*** Pollen grains are in tetrahedral tetrads, tetrad axis (D) 25.68–35.4 (31.08) µm, oblate, equatorial axis (E or d) 20.58–29.14 (24.13) µm, polar axis (P) 13.7–26.17 (18.32) µm, P/E ratio 0.65–0.97 (0.82), D/d ratio 1.13–1.36 (1.27). Colpus is narrowing, colpus margin distinct. Ora is in the middle of the colpus, length (2f) 9.45–19.78 (17.04) µm, width (W) 1.43–3.08 (2.35) µm. Septum thickness (Se) 1.32–2.09 (1.69) µm thick, exine (Ex) 1.44–1.68 (1.59) µm thick, regulate. 2f/W ratio 6.08–8.35 (7.09) µm, 2f/D ratio 0.37–0.62 (0.51) µm. Representative micrographs of pollen under the SEM are given in Fig. 5b$_{1-4}$.

***Vaccinium uliginosum*** L. 1753, Sp. Pl. 350

***Leaf:*** Ovate-obovate with entire margin in shape (Fig. 1c$_1$). The secondary veins are opposite at the base of a primary vein and then alternatively arranged with a divergence angle of 25–45° towards the primary vein tip and anastomose. The numbers of areoles formed by the secondary, tertiary, and quaternary veins are 3–4, 1–3, and 1–2, respectively (Fig. 1c$_2$). However the quaternary veins are generally freely ending without forming any areoles. The leaf adaxial surface under SEM is covered by a distinctly rare, more or less dispersed epicuticular wax; the epidermal cell borders are slightly visible (Fig. 2c$_{1-3}$).

***Seed:*** Seeds are 1–1.1 mm length, light or dark brown, lunate to elliptic in outline (Fig. 3c). Epidermal cells of seed coat are elongated, irregular in shape, anticlinal walls obvious, smooth, thickened, slightly undulate, periclinal surfaces smooth and flat (Fig. 4c$_{1-4}$).

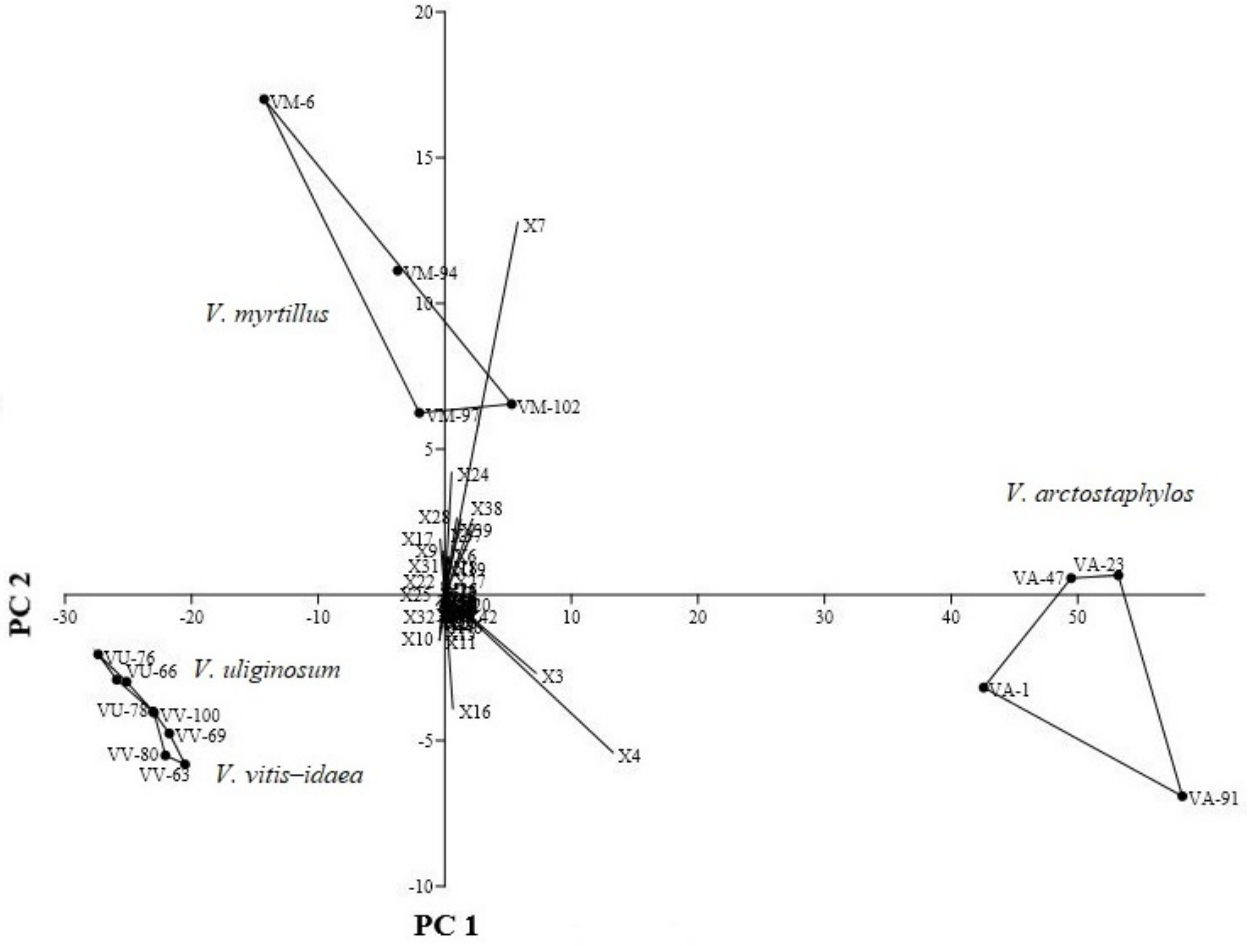


Fig. 7. Ordination resulting from principal components analysis (PCA) of *Vaccinium* based on 47 characters (Details of the population numbers and traits are given in Table 1, 2 respectively).

Table 1

Voucher data of the studied taxa *Vaccinium*

| Taxa | Pop. Code | Grid of Davis (1970) | Locality | Altitude (m) | Voucher number |
|---|---|---|---|---|---|
| *V. arctostaphylos* | VA1 | A7 | **Gümüşhane:** Kürtün above Alan Plateau | 1845 | *Coşkunçelebi & Yılmaz 1* |
| | VA23 | A7 | **Trabzon:** Tonya above Kalınçam Village | 1483 | *Coşkunçelebi & Yılmaz 23* |
| | VA47 | A8 | **Rize:** Ardeşen, Siprona Plateau | 1032 | *Coşkunçelebi & Yılmaz 47* |
| | VA91 | A8 | **Artvin:** Murgul, Tiryal Mountain | 2234 | *Coşkunçelebi & Yılmaz 91* |
| *V. myrtillus* | VM6 | A7 | **Gümüşhane:** Kürtün, Süme Village | 2081 | *Coşkunçelebi & Yılmaz 6* |
| | VM94 | A7 | **Trabzon:** Multat Plateau | 2811 | *Coşkunçelebi & Yılmaz 94* |
| | VM97 | A8 | **Artvin:** Şavşat, Kirazlı Village | 2533 | *Coşkunçelebi & Yılmaz 97* |
| | VM102 | A9 | **Ardahan:** Hanak, Alabalık Plateau | 2613 | *Coşkunçelebi & Yılmaz 102* |
| *V. uliginosum* | VU66 | A8 | **Artvin:** Şavşat, Karagöl National Park | 2537 | *Coşkunçelebi & Yılmaz 66* |
| | VU76 | A9 | **Ardahan:** Posof, Üçlıçkın Hill | 2405 | *Coşkunçelebi & Yılmaz 76* |
| | VU78 | A9 | **Ardahan:** Hanak, Alabalık Plateau | 2588 | *Coşkunçelebi & Yılmaz 78* |
| | VU93 | A7 | **Trabzon:** Multat Plateau | 2811 | *Coşkunçelebi & Yılmaz 93* |
| *V. vitis-idaea* | VV63 | A8 | **Artvin:** Şavşat, Karagöl National Park | 2533 | *Coşkunçelebi & Yılmaz 63* |
| | VV69 | A9 | **Ardahan:** Posof, Sesödile Hill | 2376 | *Coşkunçelebi & Yılmaz 69* |
| | VV80 | A9 | **Ardahan**: Alabalık Plateau | 2579 | *Coşkunçelebi & Yılmaz 80* |
| | VV100 | A8 | **Artvin:** Şavşat, Kocabey Plateau | 2491 | *Coşkunçelebi & Yılmaz 100* |

Table 2

Characters

| Acronym | Examined characters and their states |
|---|---|
| X1 | Leaf (evergreen: 0; deciduous: 1) |
| X2 | Leaf (papery: 0; coriaceous: 1) |
| X3 | Leaf width (cm) |
| X4 | Leaf length (cm) |
| X5 | Leaf shapes (elliptic-lanceolate: 1; elliptic-ovoid: 2; ovate-oblong: 3; ovate-oblong: 4) |
| X6 | Leaf margin (entire: 1; serrate 2; serrulate: 3) |
| X7 | Leaf teeth numbers in 1 cm long (digit) |
| X8 | Leaf apex (acuminate: 1; acute: 2; obtuse: 3) |
| X9 | Leaf base (oblique: 1; attenuate: 2; rounded: 3) |
| X10 | Leaf abaxial surface (pubescent: 0; glabrous: 1) |
| X11 | Leaf adaxial surface (pubescent: 0; glabrous: 1) |
| X12 | Petiole length (mm) |
| X13 | Petiole (glabrous: 0; hairy: 1) |
| X14 | Leaf venation (reticulate: 0; anastomose: 1) |
| X15 | Inflorescence (terminal: 0; axilary rasemes: 1) |
| X16 | Flower number (digit) |
| X17 | Corolla shape (campanulate: 1; urceolate: 2; spherical: 3) |
| X18 | Corolla color (white-mock: 1; white - dark red: 2; dark red-yellowish green: 3) |
| X19 | Corolla width (mm) |
| X20 | Corolla length (mm) |
| X21 | Calyx length (mm) |
| X22 | Calyx margin (narrow-wide triangular: 1; wavy: 2; rounded-undulate: 3) |
| X23 | Calyx (pubescent: 0; glabrous: 1) |
| X24 | Pedicel length (mm) |
| X25 | Fruit color (coal black: 1; black: 2; indigo: 3; sour cherry: 4) |
| X26 | Average weight of 10 air dried fruit/mg |
| X27 | Pedicel length in fruiting (cm) |
| X28 | Dried fruit diameter (mm) |

Table 2 (continuation)

| Acronym | Examined characters and their states |
|---|---|
| X29 | Seed length (mm) |
| X30 | Leaf surface under SEM (fibros-striat: 1; ruminate: 2; concave-postulate :3) |
| X31 | Areoles shape (ovoid: 0; diagonal: 1) |
| X32 | Number of secondary veins (10–16: 0; 8–10: 1) |
| X33 | Areoles number of secondary vein (16–18: 1; 10–14: 2; 6–8: 3) |
| X34 | Seed surface under SEM (wrinkled: 0; wavy: 1) |
| X35 | Seed epidermal cells shape (isolateral or quadrilateral: 0; elengote: 1) |
| X36 | Anticlinal wall of the seed epidermal cells (smooth: 0; ruminate: 1) |
| X37 | Tetrad axis (D) (μm) |
| X38 | Equatorial axis (E or d) (μm) |
| X39 | Polar length (P) (μm) |
| X40 | P/E (μm/μm) |
| X41 | D/E (μm/μm) |
| X42 | Colpus length (2f) (μm) |
| X43 | Colpus width (W) (μm) |
| X44 | Septum thickness (Se) (μm) |
| X45 | Exine (Ex) (μm) |
| X46 | 2f/W (μm/μm) |
| X47 | 2f/D (μm/μm) |

***Pollen grains:*** Pollen grains are in tetrahedral tetrads, tetrad axis (D) 21.47–28.95 (24.59) μm, oblate, equatorial axis (E or d) 17.83–25.43 (20.77) μm, polar axis (P) 11.96–17.94 (14.51) μm, P/E ratio 0.63–0.77 (0.64) μm, D/d ratio 1.14–1.39 (1.27) μm. Colpus is narrowing, colpus margin distinct. Ora is in the middle of the colpus, length (2f) 10.3–17.45 (15.47) μm, width (W) 1.83–2.88 (2.48) μm. Septum thickness (Se) 0.97–1.44 (1.25) μm thick, exine (Ex) 1.32–1.53 (1.42) μm thick, rugulose. 2f/W ratio 5.63–6.99 (6.26) μm, 2f/D ratio 0.49–0.88 (0.65) μm. Representative micrographs of pollen under the SEM are given in Fig. $5c_{1-4}$.

***Vaccinium vitis-idaea*** L. 1753, Sp. Pl. 351

***Leaf:*** Ovate-obovate with entire margin in shape (Fig. $1d_1$). The secondary veins are opposite at the base of a primary vein and then alternatively arranged with a divergence angle of 25°–45° towards the primary vein tip and free-ending. The numbers of areoles formed by the secondary, tertiary, and quaternary veins are 3–4, 1–3, and 1–3, respectively (Fig. $1d_2$). The leaf adaxial surface is covered by a distinctly dense dispersed epicuticular waxes; the epidermal cell borders are slightly visible (Fig. $2d_{1-3}$).

***Seed:*** Seeds are 1.3–1.5 (1.4) mm length, light or dark brown, lunate to falcate (Fig. 3d). Epidermal cells of seed coat are elongated, irregular in shape, anticlinal walls obvious, smooth, thickened, slightly undulate, periclinal surfaces smooth and flat (Fig. 4d).

***Pollen grains:*** Pollen grains are in tetrahedral tetrads, tetrad axis (D) 24.38–34.74 (27.14) μm, oblate-spheroidal, equatorial axis (E or d) 12.96–22.48 (18.7) μm, polar axis (P) 12.03–18.32 (14.86) μm, P/E ratio 0.71–0.92 (0.84) μm, D/d ratio 1.32–1.39 (1.36) μm. Colpus is narrowing, colpus margin distinct. Ora is in the middle of the colpus, length (2f) 14.37–23.85 (17.68) μm, width (W) 1.52–3.15 (2.67) μm. Septum thickness (Se) 0.89–1.52 (1.18) μm thick, exine (Ex) 1.18–1.26 (1.2) μm thick, regulate. 2f/W ratio 5.45–9.12 (7.94) μm, 2f/D ratio 0.61–0.83 (0.81) μm. Representative micrographs of pollen under the SEM are given in Fig. $5d_{1-4}$.

**Numerical results**

Scores related to leaf, flower, fruit and seed and pollen traits of 16 populations belonging to four wild *Vaccinium* were given in Table 4. The dendrogram resulting from the cluster analysis (UPGMA) based on the combined dataset (36 morphological: flower: 9, leaf: 18, seed and fruit: 9) and 11 palynological characters) is given in Fig. 6. The dendrogram revealed that the examined *V. arctostaphylos* specimens (label b) are distinctly separated from the rest of the examined *Vaccinium* specimens (label a) at a distance value of 67.5. Moreover, specimens of *V. uliginosum* and *V. vitis-idaea* are aggregated at a distance value of 7.5, which shows that they are the most closely related taxa based on both morphological and palynological characters (Fig. 6).

Table 3

Scores of forty seven traits of examined population belong to *Vaccinium* (Explanation of the population number and traits are given in Table 1,2 respectively

| Traits | Statistics | VA1 | VA23 | VA47 | VA91 | VM6 | VM94 | VM97 | VM102 | VU66 | VU78 | VU93 | VU76 | VV63 | VV69 | VV80 | VV100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **X1** | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| **X2** | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| **X3** | Mean | 34.70 | 33.00 | 41.50 | 46.60 | 9.00 | 12.75 | 14.25 | 20.33 | 6.43 | 5.60 | 8.58 | 6.72 | 8.62 | 7.75 | 7.92 | 6.50 |
| | SD | ±0.16 | ±0.12 | ±0.14 | ±0.20 | ±0.26 | ±0.18 | ±0.16 | ±0.25 | ±0.55 | ±0.39 | ±0.47 | ±0.35 | ±0.15 | ±0.22 | ±0.18 | ±0.21 |
| **X4** | Mean | 65.85 | 75.99 | 67.3 | 77.87 | 13.25 | 24.00 | 27.75 | 32.30 | 12.01 | 9.49 | 13.65 | 10.09 | 16.36 | 14.89 | 14.61 | 13.68 |
| | SD | ±1.25 | ±1.28 | ±1.17 | ±1.21 | ±0.95 | ±1.04 | ±0.93 | ±0.97 | ±0.24 | ±0.32 | ±0.28 | ±0.17 | ±0.22 | ±0.28 | ±0.19 | ±0.21 |
| **X5** | | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| **X6** | | 2 | 3 | 2 | 3 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| **X7** | Mean | 23.44 | 30.53 | 29.11 | 25.16 | 19.5 | 19.25 | 13.5 | 17.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | SD | ±1.12 | ±0.85 | ±0.96 | ±1.02 | ±0.65 | ±0.74 | ±1.17 | ±1.11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **X8** | | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| **X9** | | 1 | 1 | 1 | 1 | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| **X10** | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **X11** | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **X12** | Mean | 0.1 | 0.1 | 0.1 | 0.1 | 0.98 | 1.06 | 0.8 | 0.95 | 0.94 | 1.11 | 0.95 | 1.06 | 1.7 | 1.72 | 1.61 | 2.01 |
| | SD | ±0.24 | ±0.19 | ±0.25 | ±0.29 | ±0.17 | ±0.22 | ±0.14 | ±0.12 | ±0.01 | ±0.02 | ±0.04 | ±0.03 | ±0.02 | ±0.01 | ±0.03 | ±0.04 |
| **X13** | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| **X14** | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| **X15** | | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **X16** | Mean | 5.30 | 4.70 | 5.90 | 6.20 | 0 | 0 | 0 | 0 | 1.50 | 2.00 | 1.50 | 1.50 | 4.00 | 4.00 | 5.50 | 4.00 |
| | SD | ±0.46 | ±0.75 | ±0.63 | ±0.92 | 0 | 0 | 0 | 0 | ±0.21 | ±0.49 | ±0.73 | ±0.54 | ±0.25 | ±0.15 | ±0.42 | ±0.50 |
| **X17** | | 1 | 1 | 1 | 1 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 |
| **X18** | | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| **X19** | Mean | 5.7 | 4.02 | 5.89 | 4.06 | 4.5 | 3.87 | 4.25 | 5.48 | 3.02 | 2.72 | 2.87 | 2.95 | 3.35 | 3.4 | 4.07 | 3.43 |
| | SD | ±0.85 | ±0.92 | ±0.79 | ±0.81 | ±0.24 | ±0.32 | ±0.28 | ±0.31 | ±0.45 | ±0.38 | ±0.42 | ±0.37 | ±0.23 | ±0.19 | ±0.25 | ±0.28 |

Table 3 (continuation)

| Traits | Statistics | VA1 | VA23 | VA47 | VA91 | VM6 | VM94 | VM97 | VM102 | VU66 | VU78 | VU93 | VU76 | VV63 | VV69 | VV80 | VV100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **X20** | Mean | 7.1 | 7.19 | 7.8 | 3.86 | 3.86 | 4.3 | 3.96 | 4.67 | 3.06 | 3.15 | 3.7 | 3.23 | 4.66 | 4.26 | 4.25 | 4.4 |
| | SD | ±1.15 | ±1.18 | ±1.11 | ±0.94 | ±0.95 | ±0.93 | ±1.04 | ±1.08 | ±0.18 | ±0.23 | ±0.14 | ±0.16 | ±0.94 | ±0.79 | ±0.83 | ±0.97 |
| **X21** | Mean | 3.87 | 3.58 | 3.3 | 3.36 | 2.27 | 1.78 | 2.55 | 2.49 | 1.84 | 1.89 | 1.55 | 1.86 | 2.08 | 1.88 | 1.94 | 1.83 |
| | SD | ±0.12 | ±0.13 | ±0.14 | ±0.12 | ±0.24 | ±0.15 | ±0.32 | ±0.17 | ±0.11 | ±0.22 | ±0.14 | ±0.17 | ±0.25 | ±0.23 | ±0.19 | ±0.34 |
| **X22** | | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 |
| **X23** | | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| **X24** | Mean | 4.53 | 7.19 | 4.82 | 6.68 | 12.39 | 2.05 | 6.83 | 7.12 | 2.89 | 3.16 | 2.6 | 2.87 | 2.6 | 3.68 | 3.22 | 2.62 |
| | SD | ±0.15 | ±0.18 | ±0.14 | ±0.11 | ±0.37 | ±0.32 | ±0.27 | ±0.31 | ±0.18 | ±0.13 | ±0.24 | ±0.16 | ±0.23 | ±0.19 | ±0.17 | ±0.25 |
| **X25** | | 1 | 1 | 2 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 |
| **X26** | Mean | 0.87 | 0.82 | 0.86 | 0.63 | 1.12 | 0.93 | 0.78 | 0.65 | 0.36 | 0.46 | 0.38 | 0.43 | 0.22 | 0.28 | 0.32 | 0.25 |
| | | ±0.14 | ±0.19 | ±0.11 | ±0.18 | ±0.78 | ±0.74 | ±0.68 | ±0.15 | ±0.17 | ±0.09 | ±0.18 | ±0.21 | ±0.18 | ±0.22 | ±0.19 | |
| **X27** | Mean | 6.28 | 4.8 | 6.15 | 4.83 | 4.17 | 5.18 | 4.25 | 5.43 | 3.93 | 3.08 | 3.52 | 3.87 | 4.04 | 3.96 | 4.37 | |
| | SD | ±1.27 | ±1.12 | ±1.25 | ±1.19 | ±1.09 | ±1.15 | ±1.11 | ±1.13 | ±0.72 | ±0.69 | ±0.75 | ±0.71 | ±0.85 | ±0.86 | ±0.89 | |
| **X28** | Mean | 6.77 | 5.67 | 7.13 | 7.14 | 4.25 | 7.11 | 5.94 | 9.12 | 2.25 | 2.67 | 2.13 | 2.26 | 2.81 | 2.03 | 1.98 | 2.78 |
| | SD | ±0.18 | ±0.08 | ±0.14 | ±0.10 | ±0.28 | ±0.21 | ±0.19 | ±0.27 | ±0.49 | ±0.39 | ±0.43 | ±0.48 | ±0.39 | ±0.24 | ±0.28 | ±0.35 |
| **X29** | Mean | 1.34 | 1.42 | 1.53 | 1.38 | 1.28 | 1.35 | 1.27 | 1.25 | 1.18 | 1.05 | 1.12 | 1.07 | 1.45 | 1.37 | 1.38 | 1.53 |
| | SD | ±0.08 | ±0.05 | ±0.10 | ±0.07 | ±0.05 | ±0.09 | ±0.07 | ±0.04 | ±0.19 | ±0.12 | ±0.07 | ±0.12 | ±0.01 | ±0.03 | ±0.01 | ±0.02 |
| **X30** | | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 |
| **X31** | | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **X32** | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **X33** | | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| **X34** | | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **X35** | | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **X36** | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| **X37** | Mean | 36.11 | 38.01 | 35.22 | 37.65 | 30.07 | 32.13 | 31.15 | 30.97 | 25.29 | 24.52 | 23.93 | 24.64 | 26.83 | 27.39 | 25.94 | 28.42 |
| | SD | ±1.27 | ±2.20 | ±3.05 | ±1.87 | ±2.68 | ±3.84 | ±2.77 | ±5.03 | ±3.21 | ±4.80 | ±4.78 | ±5.02 | ±3.91 | ±4.03 | ±2.14 | ±4.12 |

Table 3 (continuation)

| Traits | Statistics | VA1 | VA23 | VA47 | VA91 | VM6 | VM94 | VM97 | VM102 | VU66 | VU78 | VU93 | VU76 | VV63 | VV69 | VV80 | VV100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **X38** | Mean | 28.15 | 30.27 | 31.85 | 29.17 | 23.44 | 24.7 | 25.46 | 22.93 | 21.14 | 20.12 | 20.18 | 21.65 | 17.99 | 19.09 | 18.63 | 19.12 |
| | SD | ±2.46 | ±4.13 | ±3.60 | ±3.45 | ±3.74 | ±1.25 | ±4.10 | ±2.88 | ±4.16 | ±3.43 | ±2.63 | ±2.15 | ±2.42 | ±1.80 | ±3.12 | ±1.15 |
| **X39** | Mean | 18.82 | 21.24 | 23.02 | 19.25 | 17.66 | 18.48 | 19.12 | 18.04 | 13.27 | 14.63 | 15.88 | 14.27 | 14.22 | 14.7 | 14.56 | 15.96 |
| | SD | ±3.11 | ±1.39 | ±1.55 | ±4.71 | ±4.12 | ±1.69 | ±1.18 | ±1.64 | ±3.11 | ±2.29 | ±2.17 | ±3.20 | ±1.12 | ±3.17 | ±2.39 | ±3.30 |
| **X40** | Mean | 0.64 | 0.93 | 0.86 | 0.83 | 0.87 | 0.83 | 0.77 | 0.82 | 0.56 | 0.62 | 0.75 | 0.66 | 0.86 | 0.87 | 0.88 | 0.75 |
| | SD | ±0.13 | ±0.24 | ±0.27 | ±0.5 | ±0.22 | ±0.17 | ±0.21 | ±0.13 | ±0.40 | ±0.28 | ±0.13 | ±0.23 | ±0.31 | ±0.44 | ±0.21 | ±0.23 |
| **X41** | Mean | 1.35 | 1.34 | 1.25 | 1.43 | 1.29 | 1.32 | 1.22 | 1.25 | 1.31 | 1.29 | 1.18 | 1.33 | 1.34 | 1.37 | 1.51 | 1.45 |
| | SD | ±0.41 | ±0.95 | ±0.93 | ±0.92 | ±0.91 | ±0.45 | ±0.94 | ±0.97 | ±1.02 | ±0.38 | ±0.99 | ±0.24 | ±0.44 | ±0.33 | ±0.98 | ±0.92 |
| **X42** | Mean | 20.85 | 23.37 | 22.45 | 21.15 | 16.13 | 17.57 | 16.91 | 17.55 | 14.6 | 15.04 | 16.32 | 15.91 | 17.07 | 18.09 | 18.01 | 17.58 |
| | SD | ±2.78 | ±4.11 | ±1.3 | ±4.12 | ±2.10 | ±2.52 | ±2.73 | ±3.14 | ±3.72 | ±0.17 | ±1.36 | ±3.18 | ±2.18 | ±2.5 | ±3.12 | ±2.84 |
| **X43** | Mean | 2.68 | 2.8 | 2.75 | 2.56 | 2.45 | 2.15 | 2.42 | 2.38 | 2.45 | 2.63 | 2.48 | 2.39 | 2.55 | 2.74 | 2.69 | 2.72 |
| | SD | ±0.30 | ±1.04 | ±0.84 | ±0.93 | ±0.75 | ±1.74 | ±1.13 | ±1.10 | ±1.25 | ±0.25 | ±0.44 | ±1.05 | ±1.43 | ±1.13 | ±1.15 | ±1.18 |
| **X44** | Mean | 1.55 | 1.33 | 1.46 | 1.52 | 1.63 | 1.81 | 1.79 | 1.53 | 1.25 | 1.17 | 1.22 | 1.38 | 1.06 | 1.3 | 1.22 | 1.29 |
| | SD | ±0.39 | ±0.15 | ±0.77 | ±0.27 | ±0.94 | ±0.38 | ±0.70 | ±0.19 | ±0.82 | ±0.71 | ±0.16 | ±0.94 | ±0.19 | ±0.10 | ±0.97 | ±0.82 |
| **X45** | Mean | 1.52 | 1.9 | 1.87 | 1.59 | 1.65 | 1.59 | 1.44 | 1.68 | 1.32 | 1.48 | 1.53 | 1.35 | 1.18 | 1.22 | 1.26 | 1.13 |
| | SD | ±0.92 | ±0.32 | ±1.09 | ±0.19 | ±0.44 | ±0.66 | ±0.81 | ±0.33 | ±0.74 | ±0.56 | ±0.90 | ±0.29 | ±0.74 | ±0.39 | ±0.54 | ±0.46 |
| **X46** | Mean | 9.22 | 9.15 | 9.15 | 9.14 | 6.57 | 6.52 | 8.29 | 7.01 | 5.8 | 5.71 | 6.98 | 6.55 | 6.91 | 6.8 | 8.99 | 9.06 |
| | SD | ±2.24 | ±1.24 | ±2.65 | ±1.84 | ±1.63 | ±2.74 | ±1.15 | ±2.25 | ±2.19 | ±1.84 | ±1.14 | ±1.15 | ±1.73 | ±1.14 | ±3.10 | ±1.75 |
| **X47** | Mean | 0.48 | 0.35 | 0.55 | 0.51 | 0.51 | 0.5 | 0.48 | 0.52 | 0.74 | 0.77 | 0.62 | 0.5 | 0.9 | 0.91 | 0.69 | 0.71 |
| | SD | ±1.83 | ±0.07 | ±0.24 | ±0.29 | ±0.25 | ±0.14 | ±0.13 | ±0.20 | ±0.31 | ±0.20 | ±0.13 | ±0.24 | ±0.18 | ±0.19 | ±0.29 | ±0.20 |

Table 4

Eigen values of the characters on the first five principal components
(Explanation of traits are given in Table 2)

| Acronym | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 |
|---|---|---|---|---|---|
| X1 | 0.005 | 0.029 | –0.062 | –0.132 | –0.027 |
| X2 | –0.005 | –0.029 | 0.062 | 0.132 | 0.027 |
| X3 | **0.430** | –0.160 | **–0.781** | **0.312** | 0.029 |
| X4 | **0.795** | **–0.323** | **0.332** | –0.229 | –0.123 |
| X5 | –0.025 | –0.033 | 0.003 | 0.000 | 0.001 |
| X6 | 0.018 | 0.078 | 0.025 | 0.001 | –0.036 |
| X7 | **0.344** | **0.769** | 0.089 | 0.028 | 0.104 |
| X8 | –0.022 | –0.025 | 0.025 | 0.090 | 0.033 |
| X9 | –0.007 | 0.089 | 0.027 | 0.170 | 0.057 |
| X10 | –0.012 | –0.046 | 0.010 | –0.008 | –0.006 |
| X11 | –0.012 | –0.046 | 0.010 | –0.008 | –0.006 |
| X12 | –0.016 | –0.012 | 0.043 | 0.107 | 0.039 |
| X13 | –0.005 | –0.029 | 0.062 | 0.132 | 0.027 |
| X14 | –0.006 | –0.017 | –0.051 | –0.141 | –0.034 |
| X15 | 0.000 | –0.059 | 0.017 | –0.018 | –0.015 |
| X16 | 0.038 | –0.234 | 0.135 | **0.358** | 0.021 |
| X17 | –0.008 | 0.101 | –0.087 | –0.104 | –0.004 |
| X18 | 0.005 | 0.076 | 0.034 | 0.160 | 0.049 |
| X19 | 0.021 | 0.051 | –0.053 | 0.166 | 0.079 |
| X20 | 0.043 | –0.023 | 0.077 | 0.124 | 0.108 |
| X21 | 0.021 | –0.001 | 0.020 | 0.009 | –0.050 |
| X22 | –0.014 | 0.024 | –0.121 | –0.265 | –0.054 |
| X23 | –0.007 | 0.042 | –0.069 | –0.123 | –0.019 |
| X24 | 0.031 | **0.252** | –0.014 | 0.279 | **–0.848** |
| X25 | –0.029 | –0.002 | 0.018 | 0.167 | 0.086 |
| X26 | 0.005 | 0.032 | –0.003 | –0.011 | –0.004 |
| X27 | 0.021 | 0.026 | –0.011 | 0.085 | 0.174 |
| X28 | 0.056 | 0.157 | –0.195 | 0.067 | **0.273** |
| X29 | 0.002 | –0.001 | 0.019 | 0.042 | 0.022 |
| X30 | –0.019 | –0.016 | 0.055 | 0.142 | 0.035 |
| X31 | –0.000 | 0.059 | –0.017 | 0.018 | 0.015 |
| X32 | –0.012 | –0.046 | 0.010 | –0.008 | –0.006 |
| X33 | –0.025 | –0.033 | 0.003 | 0.000 | 0.001 |
| X34 | –0.013 | 0.012 | –0.007 | 0.009 | 0.008 |
| X35 | –0.013 | 0.012 | –0.007 | 0.009 | 0.008 |
| X36 | –0.005 | –0.029 | 0.062 | 0.132 | 0.027 |
| X37 | **0.143** | 0.143 | **0.247** | 0.219 | 0.098 |
| X38 | **0.130** | 0.157 | –0.093 | **–0.364** | 0.088 |
| X39 | 0.075 | 0.155 | 0.018 | 0.046 | **0.228** |
| X40 | 0.001 | 0.004 | 0.013 | 0.028 | 0.001 |
| X41 | 7,70E–01 | –0.005 | 0.010 | 0.018 | –0.000 |
| X42 | 0.073 | –0.047 | **0.246** | 0.202 | 0.154 |
| X43 | 0.001 | –0.014 | 0.022 | 0.023 | –0.019 |
| X44 | 0.002 | 0.023 | –0.010 | –0.001 | 0.020 |
| X45 | 0.005 | 0.016 | –0.009 | –0.026 | –0.005 |
| X46 | 0.028 | –0.046 | 0.130 | 0.216 | 0.065 |
| X47 | –0.003 | –0.011 | –0.003 | 0.021 | 0.004 |
| Eigenvalues | 1013,18 | 45.638 | 7.787 | 5.054 | 4.212 |
| Percentage | 93.613 | 4.264 | 0.719 | 0.466 | 0.389 |
| Cumulative Percentage | 93.566 | 97.877 | 98.596 | 99.062 | 99.451 |

The positions of all investigated populations belonging to the Turkish *Vaccinium* and variable that explained most of the total variation using the first two components of the PCA are given in Fig. 7. Although the first extracted components explain 93.61 % of the total variation among the examined taxa, the first three components were considered due to height Eigenvalues and those account for 93.61 %, 4.21 %, and 0.71 % of the total variation, respectively (Table 3). As seen in Table 3, the first component emphasizes that the characters contributing most to the separation of the examined taxa are leaf length (0.79), leaf width (0.43), leaf teeth numbers in 1 cm long (0.34), tetrad axis (0.14), equatorial axis (0.13) and polar axis (0.07). The second component emphasizes that both leaf teeth numbers in 1 cm long (0.76) and leaf length (0.32) and also pedicel length (0.25) contributing most to the separation of the examined taxa. Besides the third component emphasized that leaf width (0.78) and leaf length (0.33) and both tetrad axis and colpus length (0.24) contribute most to the separation of the examined taxa (Table 3).

## Discussion

The genus *Vaccinium* was investigated worldwide by several researchers (Sleumer, 1941; Camp, 1945; Stevens 1969, 1971) based on limited morphological characters (Vander Kloet, 1988). Although Odell and Vander Kloet (1991) reported that vegetative and generative characters are valuable to distinguish members of *Vaccinium,* Stevens (1971) emphasized that the many floral characters like calyx shape, corolla shape, and stamen supply limited information to distinguish taxa within the genus *Vaccinium*. Present study showed that leaf and pollen traits supply more informative data at the species level than flower and fruit traits to separate the examined *Vaccinium* taxa in Turkey (Table 2, 3).

The current study also supplies several new data for the surface sculpturing and venation type of leaf and seed length which are not specified before by Stevens (1978) in the "Flora of Turkey" and any other studies regarding *Vaccinium* in Turkey (Tables 2, 3). Although veining type was not investigated by Stevens (1978), its taxonomic importance was emphasized in the "Flora of China" (Fang, Stevens, 2005). Moreover, Pedraza-Penalosa et al. (2013) reported that leaf venation type is not affected by environmental conditions. In the present study, it was found that the vein islets of secondary veins are 8–9 in *V. arctostaphylos*, 5–7 in *V. myrtillus,* 3–4 in *V. uliginosum,* and *V. vitis-idaea* (Fig. 1), which are compatible with the "Flora of China" (Fang, Stevens, 2005) and Pedraza-Penalosa et al. (2013). However, Powell and Vander Kloet (1997) reported that the foliar venation does not always supply valuable data at the species level as seen in *V. uliginosum* and *V. vitis-idaea* in the present study.

Odell and Vander Kloet (1991) used vegetative characters such as surface features and leaf blade size measurements to distinguish the *Vaccinium* taxa. Similarly, Pedraza-Penalosa and Luteyn (2011) described seven new species based on the leaves (shape, margins, indumentum) and floral traits (merosity, calyx, corolla, pedicel) from Andean South America. The numerical analyses indicated that leaf length (X4), leaf width (X3), and leaf teeth numbers in 1 cm long (X7) are the most valuable characters for separating the investigated *Vaccinium* species. Semerdjieva et al. (2003) indicated that the secondary sculpture (according to Barthlott, 1981) of leaf adaxial surface and adaxial cuticle thickness varied among *V. uliginosum*, *V. vitis-idaea*, and *V. myrtillus* however epicuticular structures were recorded only in *V. vitis-idaea* and *V. myrtillus.* Our observations also revealed that the leaf adaxial of *V. arctostaphylos* (Fig. 2a) is like fiber-fluted while it is ruminate in *V. myrtillus* (Fig. 2b) and *V. uliginosum* (Fig. 2c) and pustulate in *V. vitis-idaea* (Fig. 2d) due to epicuticular waxes. However epidermal cell borders are hardly indistinct in *V. arctostaphylos* (Fig. 2a), they are slightly visible in other species (Fig. 2b–d).

Szkudlarz (1999b) reported a relationship between the genus *Oxycoccus* Hill (*O. microcarpus* Turcz. ex Rupr. and *O. quadripetalus* Gilib.) and *V. vitis-idaea* based on number of locule in fruits as previously reported by Gray (1868 cited in Szkudlarz, 1999b) and frequently placing *V. vitis-idaea* in a separate genus or section. Additionally, chemotaxonomic studies also indicated differences of *V. vitis-idaea* from the remaining *Vaccinium* taxa (Gugnacka-Fiedor, 1994). However, the updated taxonomic position of *O. microcarpus* and *O. quadripetalus* Gilib. (The Plant List, 2010), the variation in the chemical composition of Turkish blueberries (Erik et al., 2020) and present findings did not support the view of Gray (1868 according to Szkudlarz, 1999b) and Gugnacka-Fiedor (1994).

The seed of *V. myrtillus, V. uliginosum,* and *V. vitis-idaea* varies from lunate to reniform or falcate in outline (Fig. 3b–d) and it is triangular, tetragonal or oval in *V. arctostaphylos* (Fig. 3a). Contrary Szkudlarz (2001) indicated that the seed shape varies

from oval to ovate in *V. myrtillus*, *V. uliginosum*, and *V. vitis-idaea*. However, the seeds length is very similar with finding of Szkudlarz (2001). The seed micromorphology of *V. arctostaphylos* was observed for the first time, however, the seed micromorphology of the rest species was investigated by Vander Kloet (1988) and Szkudlarz (2001). According to Vander Kloet (1988), Szkudlarz (2001) and Anisimova et al. (2005), the cell walls of exotesta cells are strongly lignified, thickened and obvious in *V. myrtillus*, *V. uliginosum*, and *V. vitis-idaea*. Present findings mainly support the researcher's observations.

It is well known that the dispersal unit of pollen (monads or tetrads) is an important feature in several genera of Ericaceae (e. g. *Erica* L.) (Wronska-Pilarek et al., 2018). On this basis, there are no differences in the examined *Vaccinium* taxa, however, there are significant differences among the tetrads axis. The mean measurement of tetrads is in general consistent with those reported by palynologists (Sarwar et al., 2006; Sarwar, Takahashi, 2007), although higher value ranges are generally obtained for the examined features.

Palynological features of *V. myrtillus*, *V. uliginosum,* and *V. vitis-idaea* were examined in many studies (Cockerham, Galletta, 1976; Kocon et al., 1981; Goldy et al., 1984, Sarwar et al., 2006; Sarwar, Takahashi, 2007). However, pollen features of *V. arctostaphylos* were documented for the first time and also detailed palynological observations were performed in detail based on multiple wild populations belonging to the rest of the examined *Vaccinium* taxa. The surface ornamentation of pollen grain varies from rugulate to psilate in *Vaccinium* (Sarwar et al., 2006). On the other hand, pollen surface is broadly fine verrucate in the Old World *Vaccinium* species and they have a wider variety of exine sculptures (Sarwar, Takahashi, 2007). Although pollen grains in *V. myrtillus* were recorded as verrucate by Kocon et al. (1981), the current study based on three populations showed that they are regulate (Fig. 5b). On the other hand, the pollen surface is verrucate in *V. arctostaphylos* (Fig. 5a), therefore it easily distinguishes itself from the other taxa based on the pollen surface ornamentation. Among the examined taxa, pollen grains of *V. arctostaphylos* have the longest tetrad axis (D: 28.55–43.22 μm) and that coincides with the palynological features of *V.* sect. *Hemimyrtillus* Sleumer (D: 30.1–45.0 μm) (Sarwar, Takahashi, 2007). Tetrad axis (X37) is among the most important palynological traits to delimitate the examined taxa (Table 2, 3). Correspondingly, all studied populations belonging to *V. arctostaphylos* (label b) are exclusively grouped based on the combined dataset (Fig. 6). Sarwar and Takahashi (2007) noted that the lowest value of tetrad axis presents in *V. uliginosum* and also observed similarities in exine. In the present study, the smallest pollen grain was found in *V. uliginosum* (D: 21.47–28.95 μm), nevertheless, minimum values of exine were measured in *V. vitis-idaea* (Ex: 1.1–1.37 μm). Our results corroborate Sarwar et al. (2006) which consider slight differences in tetrad size and exine surface sculpture to be corresponding to the geographical distribution. Goldy et al. (1984) noted that exine sculpture may provide beneficial data on taxonomic relationships in *Vaccinium*. However, exine does not seem to be effective to separate *Vaccinium* taxa. Powell and Kron (2002), reported a relationship between *V. cylindraceum* Smith endemic to Azores and *V. arctostaphylos* based on both nuclear and chloroplast markers. However, present pollen findings of *V. arctostaphylos* (P: 20.58 μm) and *V. cylindraceum* (P: 44.92 μm) reported by Morgado et al. (2018) are not supporting a relationship between these species.

Stevens (1978) did not use any subgeneric classification in the treatment of Turkish *Vaccinium*. However, Nekrasova (1952) accepted sectional treating for the genus *Vaccinium* in the "Flora of the USSR". According to Nekrasova (1952), *V. myrtillus* and *V. uliginosum* belong to *V.* sect. *Euvaccinium* A. Gray, *V. vitis-idaea*, and *V. arctostaphylos* belong to *V.* sect. *Vitis-idaea* (Moench) Koch. However, present findings do not support treating *V. arctostaphylos* under the *V.* sect. *Vitis-idaea* contrary to Nekrasova (1952). The results clearly showed that *V. arctostaphylos* distinguishes from the rest of the examined species with several characters (e. g. leaf adaxial surface, the seed shape and epidermal cells of the seed) and it should be treated under the *V.* sect. *Hemimyrtillus* as stated by Powell and Kron (2002). Gailite et al. (2020) reported a close relationship between *V. myrtillus* and *V. uliginosum* based on genetic and geographic distribution. A similar relationship was reported for *V. uliginosum* and *V. vitis-idaea* by Vander Kloet and Avery (2010) based on phenological characters such as timing of flowering and fruiting, the number of plump seeds per berry. The present findings (Figs. 6–7) indicated that *V. uliginosum* and *V. vitis-idaea* are closely related taxa as stated by Vander Kloet and Avery (2010) and Bjedov et al. (2021). According to Powell and Kron (2002), molecular phylogeny, however, showed that *V. myrtillus* was neither closely related to *V. vitis-idaea* in Circumboreal Region.

**Acknowledgements**

We kindly thank Dr. Murat Şirin (Central Research Laboratory Application and Research Center, Recep Tayyip Erdogan University, Rize, Turkey) for his technical assistance during the SEM studies.

## REFERENCES / ЛИТЕРАТУРА

***Anisimova G. M., Shamrov I. I., Yakovleva O. V.*** 2005. Ovule, seed and heterospermy in *Vaccinium myrtillus* (Ericaceae). *Bot. Zhurn.* 90(10): 1499–1516. [In Russian] (***Анисимова Г. М., Шамров И. И., Яковлева О. В.*** Семязачаток, семя и гетероспермия у *Vaccinium myrtillus* (Ericaceae) // Бот. журн., 2005. Т. 90, № 10. С. 1499–1516).

***Ayaz F. A, Kadıoğlu A., Bertoft E., Acar C., Turna I.*** 2001. Effect of fruit maturation on sugar and organic acid composition in two blueberries (*Vaccinium arctostaphylos* and *Vaccinium myrtillus*) native to Turkey. *New Zealand J. Crop Hort. Sci.* 29: 137–141. DOI: 10.1080/01140671.2001.9514171

***Barthlott W.*** 1981. Epidermal and seed surface characters of plants: systematic applicability and some evolutionary aspects. *Nordic J. Bot.* 3: 345–355.

***Bjedov I., Obratov-Petković D., Rakonjac V., Skočajić D., Bojović S., Marković M., Dajić-Stevanović Z.*** 2021. Nontrivial variations of morpho-anatomical leaf traits in natural south-eastern populations of *Vaccinium* species from Central Balkans. *Acta Biol. Cracov., Ser. Bot.* 63/2: 7–16.

***Camp W. H.*** 1945. The North American blueberries, with notes on other groups of Vacciniaceae. *Brittonia* 5: 203–275.

***Celik H., Serçe S.*** 2015. Wild *Vaccinium* in Turkey. *HortScience* 50: 9.

***Cockerham L., Galletta G. J.*** 1976. A survey of pollen characteristics in certain *Vaccinium* species. *J. Amer. Soc. Hort. Sci.* 101: 671–675.

***Colak N., Torun H., Gruz J., Strnad M., Subrtova M., Inceer H., Ayaz F. A.*** 2016. Comparison of phenolics and phenolic acid profiles in Conjunction with oxygen radical absorbing capacity (ORAC) in berries of *Vaccinium arctostaphylos* L. and *V. myrtillus* L. *Pol. J. Food and Nutr. Sci.* 66: 85–91. DOI: 10.1515/pjfns-2015-0053

***Coşkunçelebi K., Kandemir A., Beyazoğlu O.*** 2000. Scanning electron microscopic examination of the seeds of *Ornihogalum* L. (Liliaceae) species distributed in Black Sea Region of Turkey. *Biologia* 55(4): 397–401.

***Coşkunçelebi K., Makbul S., Okur S.*** 2016. Studies on the achene morphology of Turkish species of *Scorzonera* L. (Asteraceae) using light and scanning electron microscopy. *Phytotaxa* 247: 1–26. DOI: 10.11646/phytotaxa.247.1.1

***Cronquist A.*** 1981. An integrated system of classification of flowering plants. *Columbia University Press*, New York 1262 pp.

***Darrow G. M., Camp W. H., Fischer E., Dermen H.*** 1944. Chromosome numbers in *Vaccinium* and related groups. *Bull. Torrey Bot. Club.* 71: 498–516.

***Davis P. H.*** (Ed.). 1965. Irano Turanian region. In: *Flora of Turkey and the East Aegean Islands*. Vol. 1. Edinburgh: Edinburgh University Press. Pp. 21–26.

***Erdtman G.*** 1952. *Pollen morphology and plant taxonomy. Angiosperms*. Stockholm and Waltham: Mass.

***Erik İ., Kılıç G., Yaylı S. S., Yılmaz G., Çoşkunçelebi K., Yaylı N.*** 2020. Altitude variation in volatile composition of blueberry leaf analyzed by SPME GC-MS. *Int. J. Pharm. Investigation* 4: 519–525. DOI: 10.5530/ijpi.2020.4.90

***Fang R. Z., Stevens P. F.*** 2005. *Agapetes.* In: Z. Y. Wu, P. H. Raven (eds.). *Flora of China*. Vol. 14. Beijing: St. Louis: Missouri Botanical Garden Press. Pp. 504–517.

***Gailite A., Gaile A., Rungis D. E.*** 2020. Genetic diversity and structure of wild *Vaccinium* populations – *V. myrtillus*, *V. vitis-idaea* and *V. uliginosum* in the Baltic States. *Silva Fennica* 54, 5: 1–20. DOI: 10.14214/sf.10396

***Goldy R. G., Munoz C. E., Lyrence P. M.*** 1984. Pollen morphology of some *Vaccinium* species and their hybrids. *J. Amer. Soc. Hort. Sci.* 109: 237–244.

***Gugnacka-Fiedor W.*** 1994. *Zmienność morfologiczna i chemiczna europejskich gatunków rodzaju Vaccinium* L. [*Morphological and chemical variability of European species of the genus Vaccinium L.*]. Ph.D. Dissertation. Torun: Uniwersytet Mikolaya Kopernika. 146 pp. [In Polish]

***Hagerup O.*** 1928. Morphological and cytological studies of Bicornes. *Dansk Bot. Ark.* 6(1): 1–27.

***Khorasani M., Mehrvarz S. S., Zarre S.*** 2020. Seed morphology and testa ultrastructure in *Allium stipitatum* complex (Amaryllidaceae; *Allioideae*) and their systematic significance. *Turk. J. Bot.* 44: 618–632. DOI: 10.3906/bot-2004-25

***Kocon J., Pliszka K., Muszyński S.*** 1981. Pollen grain surface in *Vaccinium myrtillus* as seen in scanning electron microscopy. *Acta Soc. Bot. Poloniae* 50: 583–584.

***Kovach W. L.*** 2007. MVSP – A multivariate statistical Package for Windows, ver. 3.1. Pentraeth, Wales: Kovach Computing Services.

***Kron K. A., Powell E. A., Luteyn J. L.*** 2002. Phylogenetic relationships within the blueberry tribe (*Vaccinieae*, Ericaceae) based on sequence data from matK and nuclear ribosomal ITS regions, with comments on the placement of *Satyria*. *Amer. J. Bot.* 89: 327–336. DOI: 10.3732/ajb.89.2.327

***Morgado L. N., Gonçalves-Esteves V., Resendes R., Ventura M. A. M.*** 2018. A pollen inventory of endemic species from the Azores archipelago, Portugal. *Palynology* 42(2): 273–289. DOI: 10.1080/01916122.2017.1346526

***Nekrasova V. L.*** 1952. Vacciniaceae. In: V. L. Komarov (Ed.). *Flora SSSR* [*Flora of the USSR*]. Vol. 18. Moscow; Leningrad: Publishers of Academy of Sciences of USSR. Pp. 93–102. [In Russian] (***Некрасова И. Л.*** Флора СССР. Т. 18. М.; Л.: Изд-во АН СССР, 1952. С. 93–102).

***Odell E. A., Vander Kloet S. P.*** 1991. The utility of stem characters in the classification of *Vaccinium* L. (Ericaceae). *Taxon* 40: 273–283.

***Palser B. F.*** 1961. Studies of floral morphology in the Ericales. Organography and vascular anatomy in United States species of the Vacciniaceae. *Int. J. Pl. Sci.* 123(2): 79–111.

***Panda S., Kirtania I.*** 2016. Variation in *Rhododendron arboreum* Sm. complex (Ericaceae): insights from exomorphology, leaf anatomy and pollen morphology. *Modern Phytomorphol.* 9: 29–30. DOI: 10.5281/zenodo.159693

***Park J. M., Song U. S.*** 2010. Pollen morphology of the genus *Rhododendron* (Ericaceae) in Korea. *Journal of the Korean Society of Forest Science* 99(5): 663–672.

***Pedraza-Penalosa P., Luteyn J. L.*** 2011. Andean *Vaccinium* (Ericaceae: Vaccinieae): Seven new species from South America. *Brittonia* 63(2): 257–275.

***Pedraza-Penalosa P., Salinas N. R., Wheeler W. C.*** 2013. Venation patterns of neotropical blueberries (Vaccinieae: Ericaceae) and their phylogenetic utility. *Phytotaxa* 96(1): 1–53. DOI: 10.11646/phytotaxa.96.1.1

***Powell E. A., Kron K. A.*** 2002. Hawaiian blueberries and their relatives – A phylogenetic analysis of *Vaccinium* sections *Macropelma*, *Myrtillus*, and *Hemimyrtillus* (Ericaceae). *Syst. Bot.* 27(4): 768–779.

***Powell E. A., Vander Kloet S. P.*** 1997. Foliar venation characteristics of *Vaccinium* sect. *Macropelma* and sect. *Myrtillus* (Ericaceae): a comparative analysis. *Canad. J. Bot.* 75: 2015–2025.

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

***Saibaba A. M., Rao S. R. S.*** 1990. Leaf venation studies in Indian *Sida* (Malvaceae). *SIDA, Contributions to Botany* 14(2): 215–222.

***Sarwar A. K. M. Golam.*** 2007. *Pollen morphology and its systematic significance in the Ericaceae*: A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy. Sapporo, Japan: Hokkaido University. 302 pp.

***Sarwar A. K. M. Golam, Ito T., Takahashi H.*** 2006. An overview of pollen morphology and its systematic significance in *Vaccinium* L. (Ericaceae). *Jpn. J. Palynol.* 52(1): 15–34.

***Sarwar A. K. M. Golam, Takahashi H.*** 2007. An overview of pollen morphology and its systematic significance in tribe *Vaccinieae* (*Vaccinioideae*; Ericaceae). *Jpn. J. Palynol.* 53(2): 87–104.

***Schultz J. H.*** 1944. *Some cytotaxonomic and germination studies in the genus Vaccinium.* Ph.D. Dissertation. Pullman, WA, USA: Washington State University. 98 pp.

***Semerdjieva S. I., Phoenix G. K., Hares D., Gwynn-Jones D., Callaghan T. V., Sheffield*** **E.** 2003. Surface morphology, leaf and cuticle thickness of four dwarf shrubs from a sub-Arctic heath following long-term exposure to enhanced levels of UV-B. *Physiologia Plantarum* 117(2): 289–294. DOI: 10.1034/j.1399-3054.2003.00006.x

***Simpson M. G.*** 2012. *Plant Systematics*. İstanbul: Nobel Akademik Publication. 761 pp.

***Sleumer H. O.*** 1941. Vaccinioideen-Studien. *Bot. Jahrb. Syst.* 71: 375–510.

***Sneath P. H. A., Sokal R. R.*** 1973. *Numerical Taxonomy: The principles and practice of numerical classification*. San Francisco: WH Freeman and Company. 573 pp.

***Stearn W.*** 1985. *Botanical Latin*. 3th edition. North Pomfret Vermont: David & Charles Inc. 506 pp.

***Stevens P. F.*** 1969. *Taxonomic studies in the Ericaceae.* Ph.D. Dissertation. Edinburgh, Scotland: University of Edinburgh. 678 pp.

***Stevens P. F.*** 1971. A classification of the Ericaceae: subfamilies and tribes. *Bot. J. Linn. Soc.* 64: 1–53.

***Stevens P. F.*** 1978. *Vaccinium* L. In: P. H. Davis (Ed.). *Flora of Turkey and the East Aegean Islands*. Vol. 6. Edinburgh: Edinburgh University Press. Pp. 100–104.

***Sultana N., Menzel G., Heitkam T., Kojima K. K., Bao W., Serçe S.*** 2020. Bioinformatic and molecular analysis of satellite repeat diversity in *Vaccinium* genomes. *Genes* 11(5): 527.

***Szkudlarz P.*** 1999a. The morphological and anatomical structure of dry fruits in family Ericaceae. *Biol. Bull. Poznań* 36(1): 27–41.

***Szkudlarz P.*** 1999b. The morphological and anatomical structure of fleshy fruits in family Ericaceae. *Biol. Bull. Poznań* 36(1): 43–56.

***Szkudlarz P.*** 2001. Morphological and anatomical structure of seed in the family of Ericaceae. *Biol. Bull. Poznań* 38(2): 113–132.

***Terzioğlu S. 2012.*** Ericacea**e**. In: A. Güner, S. Aslan, T. Ekim, M. Vural, M. T. Babaç (Ed.). *Türkiye Bitkileri Listesi* [*Turkey Plants List*]. İstanbul: Nezahat Gökyiğit Botanik Bahçesi Yayınları. Pp. 410–413. [In Turkish].

*The Plant List.* 2010. Version 1. URL: http://www.theplantlist.org/ (Accessed 10 January 2021).

***Vander Kloet S. P.*** 1988. *The genus Vaccinium in North America*. Ottawa: Research Branch, Agriculture Canada. 201 pp.

***Vander Kloet S. P., Avery T. S.*** 2010. *Vaccinium* on the edge. *Edinburgh J. Bot.* 67(1): 7–24.

***Vardar Y.*** 1962. *Botanikte Preperasyon Tekniği* [*Preparation Technique in Botany*]. İzmir: Ege University Matbaası kitapları. 66 pp. [In Turkish].

***Wronska-Pilarek D., Szkudlarz P., Bocianowski J.*** 2018. Systematic importance of morphological features of pollen grains of species from *Erica* (Ericaceae) genus. *PLOS ONE* 13, 10: 1–31.

***Young S. B.*** 1970. On the taxonomy and distribution of *Vaccinium uliginosum*. *Rhodora* 72: 439–459.