

Phenotypic characteristics of black apricot *Prunus* × *dasycarpa* cultivar 'Shlor-Tsiran' in Armenia

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ABSTRACT

'Shlor-Tsiran' (literally called 'Plum-Apricot') is an old black apricot cultivar, which is traditionally cultivated in Armenia. Taxonomically, it belongs to *Prunus* × *dasycarpa* Ehrh., which is a spontaneous hybrid of apricot and cherry plum (*P. armeniaca* L. × *P. cerasifera* Ehrh.). Currently, 'Shlor-Tsiran' is considered to be very rare in Armenia and it occurs as single trees in old home orchards of the Ararat Valley. It is characterised by high frost and disease resistance, late flowering and fruiting compared with other cultivated apricots, and is of interest for the development of apricot cultivars displaying delayed fruit ripening and enhanced frost resistance. This study aims to phenotype the cv. 'Shlor-Tsiran' taking into consideration 67 quantitative and qualitative characteristics of vegetative and generative organs, growth and development. Morphological description of the cv. 'Shlor-Tsiran', comparing with its parent species, *P. armeniaca* and *P. cerasifera*, was performed. Data on fertility and viability of pollen grains, biochemical and nutritional properties of fruits and tree productivity are provided. The data obtained should contribute to a wider use and conservation of the black apricot cv. 'Shlor-Tsiran' gene pool, which can be used for breeding purposes as well. The article is illustrated with tables and original photographs.

Keywords: fruits biochemical properties morphology, heirloom cultivar, plum apricot hybrid, pollen fertility and viability

INTRODUCTION

The black apricot *Prunus* × *dasycarpa* Ehrh. was described by Jakob Friedrich Ehrhart (1791). Its transitional characteristics between apricot and plum have been noticed later by Duhamel (1812), who traced its origins to the Orient and described in detail its characteristics and variability. According to Kostina (1936), *Prunus* × *dasycarpa* is a spontaneous natural hybrid of *Prunus armeniaca* L. and *P. cerasifera*

Ehrh. Its hybridisation has been likely facilitated by the concurrent cultivation of these species, marked by synchronised flowering phases and practised by seed propagation of fruit trees in the areas of origin (Kostina, 1936). Furthermore, Kostina suggested that black apricot hybrids could have appeared independently in Western China, Central Asia, Iran and Western Asia, grouping them into two main groups, namely, *Armeniaca* × *leiocarpa*

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Kostina with glabrous fruits ('Zarolu' and 'Uryuk-Plum' varieties) and *Armeniaca* × *dasycarpa* (Ehrh.) Borkh. with pubescent fruits, including eight cultivars – 'Kizil-Olkhod', 'Kara-Olkhod', 'Olkhod-Mali', 'Irani-Olu', 'Alexandria Black' (Arabian), 'Shlor-Tsiran' (literally called 'Plum-Apricot' and erroneously called 'Tlor-Tsiran' by Michurin), purple large-fruited and purple small-fruited, as well as several sterile forms (Michurin, 1908; Kostina, 1936, 1941, 1964). Being a natural hybrid, *Prunus* × *dasycarpa* is known only from cultivation from the areas of origin, including Xinjiang, Central Asia, Afghanistan, Kashmir, Balochistan, Iran, Armenia and Eastern Europe (Kostina, 1936, 1964). Although Kostina described the different forms of *Prunus* × *dasycarpa* from natural hybridisation and folk selection as varieties, it is not really known if after their appearance these forms have been ever propagated from seeds and no wild or feral populations of black apricot seem to exist. As all these forms are grafted in their areas of origin, hereafter we mention them as cultivars. It is, however, to mention that these are not cultivars obtained through selection, but rather a pattern of different phenotypes/genotypes spread through the ancient area of apricot and cherry plum cultivation.

The black apricot cv. 'Shlor-Tsiran', a spontaneous hybrid of apricot and cherry plum (*P. armeniaca* × *P. cerasifera*) cultivated in Armenia, occupies an intermediate position between apricot and cherry plum by its morphological and biological features. It is characterised by late flowering and fruiting, a medium-late ripening period and high frost and disease resistance compared with other cultivated apricots and is of great interest for the breeding of late flowering and frost-resistant apricot cultivars (Vermishyan et al., 1958). It has low seed viability and is mainly propagated by grafting (Vermishyan et al., 1958). Its first description was given by Michurin (1908). He noted the frost resistance of trees, the taste qualities of fruits and the possibility of using them in raw and processed form. Subsequently, this cultivar was included in studies on breeding of adaptive apricot cultivars by the method of distant hybridisation (Eremin, 1985). The different cultivars of *Prunus* × *dasycarpa* are insufficiently studied. In fact, information on these cultivars is very scanty and almost no pomological data do exist.

Currently, 'Shlor-Tsiran' is very rare in Armenia. It is still preserved in the form of single trees in old home orchards of the Ararat Valley in the Ararat and Armavir provinces. According to current trends, some cultivars of apricots may disappear due to their replacement with cultivars with higher market suitability. Consequently, the study of genetic diversity of the ancient resources of apricot is highly important to plan proper measures of their protection and use.

Given its rarity, up to date 'Shlor-Tsiran' has not been phenotyped. Phenotyping is defined as a set of methodologies and protocols used to accurately measure

plant growth, morphology, architecture, function and composition at different scales (Fiorani and Schurr, 2013) and as a process of systematically determining, analysing and predicting all or a part of an organism's phenotype as well as for identifying traits such as yield and quality (Carvalho et al., 2021).

This study aims to perform phenotyping of the black apricot cv. 'Shlor-Tsiran' using morphological, phenological, palynological and biochemical characteristics that have not been previously carried out.

MATERIALS AND METHODS

Sampling and field observation localities

Sampling and field observations of the black apricot cv. 'Shlor-Tsiran' were carried out in Armavir Province of the Republic of Armenia, at the orchard with local apricot cultivars collection of the Echmiadzin Scientific Center of Agriculture and at a fruit plants nursery in the village Lenughi, located in the Ararat Valley semi-desert zone, at an altitude of 800–855 m above the sea level. The climate of the Ararat Valley is sharply continental. During the year, the mean daily temperature ranges from –3°C to 26°C. The average annual temperature is +11°C, the annual precipitation is about 300 mm and the average annual relative air humidity is 59%. Tree planting density in the collection garden is 5 m × 4 m, and the trees are 10-year-old at the time of research. The conditions are favourable for the cultivation of apricot. Samplings and measurements have been performed in triple; in each repetition, samples were collected and measurements were taken from five trees. Sampling and field observations of *P. armeniaca* and *P. cerasifera* were carried out in the Yerevan Botanical Garden NAS RA at the 'Flora and Vegetation of Armenia' exhibition plot with fruit plants living collection. The climatic indicators in the Ararat Valley are close to those in the Yerevan Botanical Garden located in the zone of stony wormwood semi-desert at an altitude of 1200–1250 m above the sea level. The absolute minimum temperature in the Yerevan Botanical Garden is 2°C–3°C which is lower than that in the Ararat Valley.

Phenotyping

Phenotyping of cv. 'Shlor-Tsiran' was performed according to UPOV (2016) (Tables 1 and 2). Tree habitus, growth and shoot characteristics, shoot growth dynamics, phenophase changes, leaves, flowers, fruits and harvest counting, depending on the crown formation, was evaluated according to the programme and methodology for studying cultivars of fruit, berry and nut crops (Sedov and Ogoltsova, 1999). Visual and measurement observation types were used. The onset of fruit ripening was assessed on trees in the orchard. The degree of separation of the kernel from the pulp and the volume of the fruit and kernel were evaluated in the laboratory. The kernel bitterness was assessed

Table 1. Leaf characteristics for the description of apricot *Prunus armeniaca* L. cultivars by UPOV (2016).

No.	Character	Unit	Min	Max	Mean
1.	Leaf length	cm	6.17	8.92	7.46
2.	Leaf width	cm	3.52	7.9	6.35
3.	Ratio of leaf length to width	code	3	7	3.68
4.	Shape of the leaf base	code	2	4	3.08
5.	Green colour intensity of the leaf surface	code	3	7	5.75
6.	Leaf apex angle	code	1	3	2.39
7.	Leaf apex length	mm	1.66	7	4.25
8.	Cut edge of leaves	code	2	4	3.19
9.	Unevenness of the leaf edge	code	3	5	4.26
10.	Petiole length	cm	2.5	5.17	3.73
11.	Leaf-to-petiole length ratio	code	5	7	5.73
12.	Petiole thickness	mm	3	7	5
13.	Number of glands in the petiole	number	1	2	1.25
14.	Average weight of 10 leaves	g	4.31	12.65	7.66

Table 2. Fruit characteristics for the description of apricot *Prunus armeniaca* L. cultivars by UPOV (2016).

No.	Character	Unit	Min	Max	Mean
1.	Fruit size	code	3	9	6.31
2.	Shape from the belly	code	1	6	2.48
3.	Shape from the back	code	2	5	3.02
4.	Height	mm	31.11	49.72	39.61
5.	Width at the belly	code	3	5	3.55
6.	Width at the back	code	3	3	3.36
7.	Back width and fruit height ratio	code	5	7	5.57
8.	Belly and back width ratio	code	5	7	5.28
9.	Symmetry at the back	code	1	3	2.46
10.	Abdominal length	code	1	4	2.47
11.	Depth of the funnel	code	3	7	5.17
12.	Apex shape	code	1	3	1.36
13.	Presence of apex	code	3	3	3
14.	Planeness of the skin	code	1	1	1
15.	Softness of the skin	code	9	9	9
16.	Shine of the skin	code	1	3	2.3
17.	Colour of the skin	code	1	3	1.88
18.	Prevalence of subcutaneous points	code	1	5	2.58
19.	Colour of subcutaneous spots	code	1	4	3.03
20.	Degree of colour intensity of subcutaneous points	code	3	5	4.6
21.	Colour of the fruit flesh	code	1	6	3.4
22.	Structure of the fruit flesh	code	1	3	2.5
23.	Degree of separation of the kernel from the pulp	code	1	3	1.36
24.	Shape of the cornice is from the belly	code	3	3	3
25.	Presence of bitterness of the kernel	code	1	1	1.05
26.	Beginning of fruit ripening	code	1	9	4.85
27.	Fruit weight	g	14.19	50.92	30.57
28.	Kernel weight	g	1.01	3.36	1.9
29.	Kernel volume	mm ³	1.50	4.20	2.58
30.	Fruit volume	mm ³	13.50	52.10	32.59
31.	Ratio of kernel to fruit weight	(%)	4.22	12.05	6.46

by tasting. Harvest time is based on changes in fruits shape, flavour and colour. The harvest amount data were analysed statistically using the dispersion analysis method, and the quantitative characteristics of the fruit and leaf were analysed according to qualitative and quantitative change methodology (Khachatryan, 2002; Mamajanyan, 2018).

Pollen fertility and viability

The measurements were carried out during the beginning of flowering in the end of March. Friable closed flowers were used to determine pollen fertility, from which the pollen was easily shaken off onto a glass slide. Pollen fertility was determined on temporary preparations stained with acetocarmine. On each preparation, 100 pollen grains were counted in three repetitions. The number of fertile (well-coloured) and sterile (not coloured or partially coloured) pollen grains was determined. To determine the germination of pollen grains, large buds were covered with paper bags and placed in a desiccator with silica gel in a refrigerator. Pollen germination was performed using a drop of an aqueous solution of sucrose at a concentration of 20%. The glass slide with pollen grains was placed in a Petri dish with highly moistened filter paper. Germinated pollen grains were counted and the length of pollen tubes was measured after 24 hr of germination. The work was carried out with a PZO Warszawa microscope using an eyepiece micrometre at a magnification of 250 $\times$. The obtained data were processed using the Excel program.

Biochemical analysis

The biochemical analysis of the fruit samples was performed using the following methods: high-performance liquid chromatography, quantitative and qualitative identification of compounds (Fратиanni et al., 2018; Forcada et al., 2019; Su et al., 2020; Tsaturyan, 2021; Petruccell et al., 2023) and physical and chemical methods of analysis (Kafkaletou et al., 2019; Zhou et al., 2020; Fratianni et al., 2022; Ulikhanyan et al., 2022). The determination of antioxidant activity was performed using the titration method of potassium permanganate in sulphuric acid solution at room temperature (Djenidi et al., 2020; Butkeviciute et al., 2022). The resulting value indicates the antioxidant activity of all biologically active substances.

Economic costs

The investment costs for planting and maintenance and the income and profit from the sale of the crop were calculated. By subtracting the investment costs from the total cash income, profit was calculated. By dividing the profit received by the invested amount and expressing it as a percentage, we obtained the economic efficiency. The cost was calculated by dividing production costs by the amount of planting material obtained per hectare (Davtyan and Voskanyan, 2004; Davtyan and Danielyan, 2007; Melqumyan, 2014; Harutunyan, 2021).

RESULTS AND DISCUSSION

Prospects for the cultivation of cv. 'Shlor-Tsiran', along with economic factors, are determined by its biological, morphological and phenological characteristics. To characterise the complex of traits of the studied crop plants and to identify valuable ones for use in fruit growing and breeding, it is important to carry out their phenotyping. Phenotyping of black apricot cv. 'Shlor-Tsiran' was carried out in the present study, using morphological, phenological, palynological and biochemical characteristics. Sixty-seven traits of black apricot 'Shlor-Tsiran' including trees growth, phenological phases of budding, flowering, fruiting and qualitative and quantitative parameters of vegetative and generative organs are presented in Table 3.

According to quantitative data, the tree crown width of trees planted in rows in a cup-shaped form should correspond to 1.3 m. As a result of studying the indicators of growth and development of the leaf surface area during the growing season, it was revealed that 'Shlor-Tsiran' has a large assimilation surface. The length of 10 leaves of the cv. 'Shlor-Tsiran' is 40 cm, the number of shoots on one tree is about 150, the number of skeletal branches is 5 and the area of one leaf is about 26 cm². Thus, the leaf area of one tree of the cv. 'Shlor-Tsiran' is about 58.500 cm². Phenotyping data revealed that 'Shlor-Tsiran' ends the vegetative growth period later than other local apricot cultivars. The duration of the growing season is about 225 days. Mass flowering is observed from 29 March to 4 April. 'Shlor-Tsiran' is a late ripening cultivar, and the fruits ripen in the first 10 days of July.

'Shlor-Tsiran' morphological description

'Shlor-Tsiran' is a tall tree with a length of 2.5–4 m with a spherical crown and greyish-brown branches (Figure 1). The number of lateral branches is up to 17. Based on the nature of growth, which is determined by the degree of deviation of the trunk from the vertical direction and curvature around its axis, it belongs to the group of cultivars with a strongly curved trunk. Branchlets are numerous, glabrous, yellowish-light-brown colour. The leaf blade is ovate to elliptic ovate, 4–8 cm $\times$ 2.5–5 cm, abaxially pubescent along veins, adaxially yellowish-green, glabrous, shortly acuminate apex, broadly cuneate to rounded basely, irregularly serrate margin and petioles of 2.5–2.8 cm thickness. Flowers are usually solitary, opening before leaves, white or pall pink, small, 1.5–1.7 cm in diameter, peduncle finely pubescent and 3–6 mm long (Figure 2A).

Corolla of 5, sometimes 6–7, petals is white, up to 8–9 mm $\times$ 6 mm, broadly elliptic to spatulate, with a short claw; hypanthium is 6 mm long, reddish, campanulate, glabrous, sepals 3.5–4.0 mm $\times$ 2.2 (2.3) mm, reddish, elliptic, glabrous, with glandular hairs along the margin, apex obtuse and peduncles of 7–12 mm length after flowering ends (Figures 2B and 2C) and stamens are 25–35 in number, 5–6 mm long, style length of

Table 3. Phenotypic characteristics of 'Shlor-Tsiran'.

Growth characteristics of black apricot cv. 'Shlor-Tsiran' 10-year-old trees	
Crown shape	Cup shaped
Tree average height	2.5 m
Degree of branching	Strong
<i>Leaf and shoot characteristics</i>	
Length of shoots/average of 10	40 cm
Number of shoots	150
Number of skeletal branches	5
Number of leaves/shoot	15
Leaf surface area	26 cm ²
Leaf length	6 cm
Leaf width	3 cm
Ratio of leaf length to width	2.7
Leaf green colour intensity	Middle
The shape of the leaf base	Rounded
The shape of the leaf apex	Suddenly shortly acuminate
Leaf apex length	7 mm
Leaf blade: profile in cross section. Edge cut	Moderately concave
Leaf blade: undulation of margin edge roughness	Weak
Petiole length	2.75 cm
Leaf-to-petiole length ratio	Large
Petiole thickness	Thin
Number of glands	1–3
Average weight of 10 leaves	5.71 g
<i>Changes in vegetative buds. Timing of defoliation and duration of vegetation with average data</i>	
Date of beginning of swelling of vegetative buds and separation of scales	20 April
Date of beginning of vegetative shoots emergence (1–5 cm)	25 April
Period of vigorous vegetative growth	5 May–10 June
Period of organisation of apical buds	01 June–20 June
Leaf fall (start/mass leaf fall/end)	10 October/20 October/29 October
Vegetation duration (days)	225
<i>Changes in generative (fruit) buds/2019–2021</i>	
Date of buds swelling	14 March
Date of buds opening	18 March
Flowering (start/mass flowering/end)	25 March/04 April/11 April
Date of beginning of fruit formation	25 May
Date of beginning of fruit ripening	24 June

(Continued)

Table 3. Continued

Growth characteristics of black apricot cv. 'Shlor-Tsiran' 10-year-old trees	
<i>Morphological characteristics of fruit</i>	
Size	Medium
Shape in ventral view	Ovate
Form of the fruit shape in lateral view	Oblong
Height	42.0 mm
Ventral width	Medium
Lateral width	Medium
Ratio of lateral width/ventral width	5.0
Ratio of height/ventral width	Medium
Fruit: symmetry in ventral view	Clearly asymmetric
Fruit: suture	Slightly sunken
Fruit: depth of stalk cavity	Medium
Shape of the apex	Flat
Fruit: shape of tip (except mucron)	Weakly depressed
Fruit: surface	Smooth
Fruit: pubescence	Present
Fruit: hue of over colour	Red
Fruit: relative area of colour	Large
Fruit: pattern of over colour	Solid flush
Fruit: intensity of over colour	Medium
Fruit: colour of flesh	Medium orange
Start of fruit ripening	Middle term ripening
Glow of the skin	No shining
Fruit: texture of flesh	Fibrous
Adherence of stone to flesh	Absent or very weak
Kernel: shape in lateral view	Ovate
Kernel: bitterness	Medium
Average fruit weight	40 g
Average fruit weight with stone	92.9/30.97 g
Average weight of kernels	5.01/1.67 g
Average weight of fruit without seed	293 g
Average content of zoles in fruit	0.5 g
Volume of juice	3 mL

10–12 mm and thinly pubescent ovary. Fruits are small, 38 mm × 40 mm × 40 mm, weighing about 25–40 g, almost spherical in shape, slightly compressed from the sides, with a rounded base and a flat top (Figure 2D). The groove is shallow, slightly deepening at the base and the funnel is spacious. The fruit peduncle is green and up to 12 mm long. The fruit skin is dense, dark purple in colour, glaucous and covered with thin velvety pubescence. The pulp is friable, somewhat mealy, low juicy, adnate to the stone, yellowish red, sweet and sour, with a slight aroma. Stone is of 2–2.6 cm × 1.4–1.7 cm × 0.8–0.9 cm, ovoid in shape with a strongly protruding keel-shaped



Figure 1. 'Shlor-Tsiran' trees at the orchard of the Echmiadzin Scientific Center of Agriculture.

central rib; surface is longitudinally furrowed, scabrous, slightly wrinkled and pitted (Figure 2E).

The kernel is bitter and rarely sweet. Flowering is observed in the end of March and the beginning of April, and fruit ripening is observed in July.

A comparative study of the morphological characteristics of black apricot cv. 'Shlor-Tsiran' confirms the intermediate position in most morphological characteristics of black apricot 'Shlor-Tsiran' between parent species of apricot and cherry plum (Table 4).

'Shlor-Tsiran' leaf blade shape is an intermediate between apricot *P. armeniaca* and cherry plum *P. cerasifera*, but the top of the leaf suddenly shortly

acuminate looks like in apricot leaf; the length of the petiole almost coincides with the length of the apricot petiole. Flower stalk length is one of the main distinguishing features of *Prunus* × *dasycarpa* cv. 'Shlor-Tsiran' (7–12 mm) and approaches with that of cherry plum, whereas in apricot flower stalk is almost absent or very short (1–2.5 mm). With bright pink colour of the sepals, it looks similar to an apricot and differs in colour from the green sepals of the cherry plum. The fruit of 'Shlor-Tsiran' is smaller than that of an apricot, which is usually pubescent. Skin colour is dark purple, pulp fibrous, juicy, sweet and sour, reminiscent of large-fruited cherry plum cultivars, but it has an

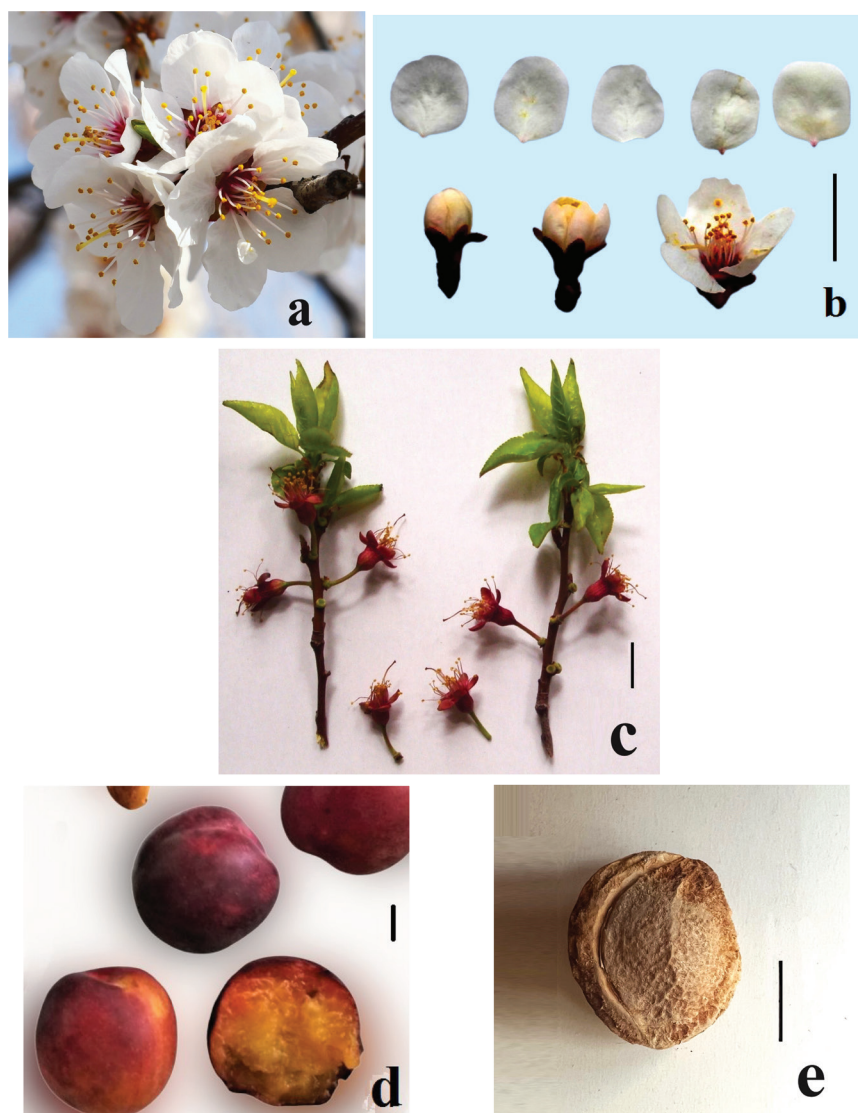


Figure 2. 'Shlor-Tsiran': (A) flowers; (B) petals, flower buds; (C) shoot fragments with hypanthium on elongated peduncles; (D) fruits and (E) stone (scale bar = 10 mm).

apricot flavour. The stone is not separated from the pulp, which is usually observed in cherry plum. Like cherry plum, black apricot 'Shlor-Tsiran' is characterised by the qualities such as winter hardiness. It tolerates spring frosts better than *P. armeniaca*, and much less often than apricots it is affected by fungal diseases such as moniliosis and clasterosporiosis, which makes this crop promising.

Pollen fertility and viability characteristics

The results of our pollen study show that, compared with its parent species, the pollen of *Prunus × dasycarpa* is characterised by smaller pollen grains, low fertility (38%), high sterility (60%) and very low germination (only 3.4%). The length of germinated pollen tubes of *Prunus × dasycarpa* after 24 hr of germination mainly ranges from 70 to 270 µm, reaching 500 µm in rare cases. In *P. armeniaca*, along with high germination, pollen tubes reach 1500–1750 µm, which makes it very

difficult to measure them. The viability of *P. cerasifera* pollen is also very high. After 6 hr of germination, it reaches 86.5% and the length of the pollen tubes is 210–840 µm. Table 5 presents some pollen characteristics of *Prunus × dasycarpa*, *P. armeniaca* and *P. cerasifera*. A decrease in pollen fertility is a characteristic of many interspecific hybrids of fruit crops of Rosaceae family (Kostina and Ryabov, 1960; Papikhin et al., 2011; Eremin, 2016, 2018). It has been established that a very low percentage of normally developed pollen grains in distant hybrids is the result of meiotic anomalies in reduction and equational divisions during microsporogenesis (Papikhin et al., 2011). In our studies, all studied accessions of *P. armeniaca* and *P. cerasifera* are characterised by a high level of fertility and viability of pollen (Table 5).

The low percentage of abortiveness and high germination of pollen of wild-growing forms of apricot in Armenia are also noted in the study by

Table 4. Comparative characteristics of *Prunus armeniaca*, *P. cerasifera* and *Prunus* × *dasycarpa* cv. 'Shlor-Tsiran'.

Character	<i>Prunus armeniaca</i>	<i>Prunus cerasifera</i>	<i>Prunus</i> × <i>dasycarpa</i> cv. 'Shlor-Tsiran'
Leaf size (cm)	6–12 × 5–11	(2)3–6 × (1)2–4	(6)6.5 × (4)4.5
Leaf shape	Ovate-rounded or broadly ovate, almost cordate at base	Oblong-elliptic or ovate-elliptic, cuneate to sub-rounded at base	Ovate to elliptic-ovate, broadly cuneate to rounded at base
Leaf apex	Suddenly shortly acuminate	Acute	Suddenly shortly acuminate
Leaf margin	Finely crenate or obtusely serrate	Finely serrated or finely blunt-serrated, rarely twice serrated	Irregularly densely finely crenate
Leaf surface	Adaxially glabrous green, abaxially matte, rarely slightly pubescent in the vein axils	Adaxially dark green, glabrous, abaxially pale green, pubescent on mid-vein	Adaxially dark green, glabrous, abaxially pubescent along veins
Petioles length (cm)	3–3.5	0.6–1.2 (2.3)	2.5–2.8
Flowers number	Usually solitary, rarely by 2	Solitary or by 2–4	Usually solitary
Sepal length (mm)	4–6	2–4	3.5–4.0
Sepals shape	Ovate to ovate oblong, acute to obtuse, glandular along the margin	Ovate, oblong-ovate, obtuse, glandular along the margin	Elliptic, obtuse, glandular along the margin
Flower peduncle length (mm)	Nearly absent to very short (1–3)	(4) 10–16 (22)	7–12
Flower colour	White or pale rose, with pink veins or pink in bud	White, sometimes pinkish at the end of flowering	White or pale rose
Corolla diameter (mm)	25–45	20–25	15–20
Hypanthium length	4–6	2–4	6
Petals shape	Elliptic or obovate, broadly elliptic	Ovate, spatulate, wavy along the edge	Elliptic or obovate
Petals size (mm)	8–12 × 6–7	7–15 × 5–10	8–9 × 6
Number of stamens	27–36	20–30	25–27(35)
Stamen length	6–10	3–6	5–6
Style length	11–15	6–7	10–12
Fruit colour	Orange, often tinged with red	Yellow, rose, red, dark violet or blackish violet	Dark violet or blackish violet
Fruit shape	Oval or sub-globose	Globose or sub-globose	Globose, slightly compressed from the sides
Fruit surface	Velvety pubescent or glabrous	Glabrous	Velvety pubescent
Fruit stalk length (mm)	Almost absent or 1–2.5	Up to 22	Up to 12
Stone shape	Ellipsoid to sub-globose, flattened, smooth, separated from the pulp	Ovoid or ellipsoidal-ovoid, wrinkled or smooth, usually not separated from the pulp	Ovoid, pitted, some wrinkled, not separated from the pulp

Hambartsumyan et al. (1977). The hybrid cv. 'Shlor-Tsiran' is, however, characterised by a significant decrease in the fertility and viability of pollen (Table 5 and Figures 3A and 3B). According to Eremin (2016, 2018), who identified four levels of incompatibility of interspecific hybrids, black apricot *Prunus* × *dasycarpa* (*P. cerasifera* × *P. armeniaca*) belongs to the second level of incompatibility of parental species. There is a decrease in pollen fertility in hybrids from crossing species at the intersectional level within one subgenus,

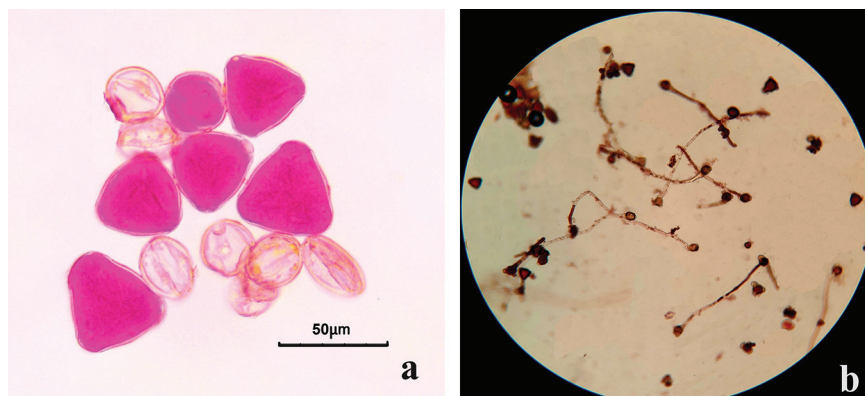
which is confirmed by the low fertility revealed by our studies in *Prunus* × *dasycarpa* cv. 'Shlor-Tsiran'.

Phytochemical characteristics

The phytochemical characteristics of 'Shlor-Tsiran' ripe fruits are reassumed in Table 6. The cultivar has some interesting phytochemical characteristics, one of which is the absence of sucrose (hence disaccharides) in the fruit pulp. Sucrose levels usually drop during fruit ripening with the resulting increase in fructose and glucose

Table 5. *Prunus* × *dasycarpa* cv. 'Shlor-Tsiran', *Prunus armeniaca* and *P. cerasifera* pollen size, fertility and viability parameters.

Pollen parameters	<i>Prunus</i> × <i>dasycarpa</i> cv. 'Shlor-Tsiran'	<i>Prunus armeniaca</i>	<i>Prunus cerasifera</i>
Size (μm)	42.5 ± 1.1	50.4 ± 0.61	45.3 ± 0.93
Fertile (%)	38.0 ± 0.79	92.9 ± 0.79	92.9 ± 0.39
Sterile (%)	58.9 ± 1.17	6.2 ± 0.43	4.5 ± 0.26
Semi-sterile (%)	3.9 ± 0.69	0.9 ± 0.15	2.7 ± 0.24
Viability (%)	3.4 ± 0.55	80.5 ± 0.5	86.5 ± 8.5

**Figure 3.** (a) Fertile (pink) and sterile (transparent) pollen grain of *Prunus* × *dasycarpa* var. 'Shlor-Tsiran'. (b) Pollen germination.**Table 6.** Phytochemical analysis of black apricot cv. 'Shlor-Tsiran'.

Tartaric acid (mg · mL ⁻¹)	0.001
Malic acid (mg · mL ⁻¹)	0.01
Citric acid (mg · mL ⁻¹)	0.011
Succinic acid (mg · mL ⁻¹)	0.005
Oxalic acid (mg · mL ⁻¹)	not detected
Fructose (% w/v)	1.935
Glucose (% w/v)	3.368
Sucrose (% w/v)	not detected
Vitamin C (% w/v)	0.0182
Antioxidant activity corresponding to the concentration of biologically active substances with reductive potential in relation to quercetin (mg/g)	4.615

(Borsani et al., 2009). 'Shlor-Tsiran' seems to contain mainly glucose. Although unusual, it somehow may reflect its hybrid nature. *P. cerasifera* is usually low in sucrose and has a higher glucose/fructose ratio (Božović et al., 2017; Murathan et al., 2020), which is however not usually the case for *P. armeniaca* (Asma and Ozturk, 2005; Alajil et al., 2021). Compared with commercial apricot cultivars, black apricot cv. 'Shlor-Tsiran' has a low-medium antioxidant potential and relatively low-medium sugar and organic acid content (Alajil et al., 2021; Tareen et al., 2021; Saeed et al., 2021).

'Shlor-Tsiran' is thus a lower-calorie, refreshing alternative to modern cultivars having lower nutritional values and thus presenting a good snack for a low-calorie diet with an adequate intake of antioxidants and vitamin

C. Its fruit has higher water and mineral content and, due to its lower preservative characteristics (lower content of sugars and organic acids), a shorter shelf life. This may be due to its relative rarity, as it gained mainly the place of a seasonal short storage fruit for the local market.

Justification of the economic efficiency of black apricot cv. 'Shlor-Tsiran'

Before implementing agronomic measures in production, their technical and economic substantiation must be completed. In this regard, it is necessary to find out that these measures respond to vital problems from the point of view of individual and national interests and correspond to market demands, and what will be the market and socio-economic consequences of increasing

Table 7. Justification of the economic efficiency of the black apricot cv. 'Shlor-Tsiran' in about 10-year-old trees with an average data of 3 years/SD = 63.88.

Yield per tree	20 kg/tree
Yield per hectare	13.3 trees · ha ⁻¹
Production cost	225 AMD = 0.5829 \$ · kg ⁻¹
Fruit market value	400 AMD = 1.0363 \$ · kg ⁻¹
Income	5320.000 AMD · ha ⁻¹ = 13.7831 \$ · ha ⁻¹
Profit	2320.000 AMD · ha ⁻¹ = 6.0107 \$ · ha ⁻¹
Profitability level	77.3%

production and increasing efficiency. Black apricot stands out for its high yield, which provides a yield of 13.3 trees per hectare.

The justification of the economic efficiency of the black apricot cultivar was obtained for about 10-year-old trees with an average data of 3 years/SD = 63.88) (Table 7). Black apricot stands out for its high yield, which provides a yield of 13.3 trees per hectare. Taking into account the costs of garden care, a high level of profit and profitability is recorded, which is evident when evaluating the economic efficiency of growing the cultivar. Ten-year-old trees in the garden, which is the object of the study, are considered productive, and the yield was high. Depending on this, we had a production cost of 225 drams = 0.5829 \$ · kg⁻¹. It was found that cv. 'Shlor-Tsiran' is a relatively profitable fruit type and fully compensates the costs of garden establishment and care. The profitability level is 77.3%. Profitability levels are even higher in subsequent years of cultivation.

Perspectives of conservation and cultivation

Although there is growing interest in the breeding of new interspecific stone fruit cultivars, the artificial hybridisation in the genus *Prunus* has shown to be rather complicated (Soldatov and Salaš, 2007; Nicolás-Almansa et al., 2023). However, a number of artificial hybrids of black apricot are known (Soldatov and Salaš, 2007; Eremin et al., 2021). Although these have been selected for commercial fruit production, it must be noted that their fruit yield is comparable to 'Shlor-Tsiran', which is a natural hybrid. The disease and frost resistance of 'Shlor-Tsiran' make it an interesting candidate for breeding programmes to develop better grafting rootstocks and promising new fruit cultivars (Eremin et al., 2021). Unfortunately, old local cultivars like 'Shlor-Tsiran' are underrepresented in germplasm collections and the decline of its cultivation is a serious threat to the conservation of this black apricot cultivar. In fact, while at least three phenotypic cultivars of 'Shlor-Tsiran' (black, pink and yellow) have been mentioned (Vermishyan et al., 1958), we could collect only one cultivar during our extensive fieldwork. The re-establishment of living collections of old native fruit cultivars and phenotypes is definitely a priority to

conserve the rich heritage of folk selection in Armenia and apricots in this sense should receive special attention, including the cultivar forms of 'Shlor-Tsiran'. Also, modern micropropagation methods, established and developed for apricot propagation, should be applied on 'Shlor-Tsiran' to achieve efficient amplification of the propagation of rare phenotypes and to conserve and cultivate this nowadays rare natural hybrid (Kovalchuk et al., 2017, 2018).

CONCLUSIONS

Prunus × *dasycarpa* Ehrh. is a spontaneous hybrid that originated independently in old gardening areas of West and Central Asia. In the article, we provided detailed phenotypic, reproductive and biochemical characteristics of the cv. 'Shlor-Tsiran' of *Prunus* × *dasycarpa*, native to Armenia. Although our results clearly demonstrate that 'Shlor-Tsiran' could bear a bigger economic importance, than it has now, its cultivation in Armenia tends to decline and, together with other native apricot cultivars, it gets mainly marginalised to home orchard gardening for family use and small local markets. Its biochemical profile shows a lower organic content than widespread commercial apricot and plum cultivars, and its delayed flowering and fruiting make it an interesting alternative for market diversification and the expansion of the fruit season. The data obtained can contribute to wider use in fruit growing and conservation of the black apricot cv. 'Shlor-Tsiran' gene pool and can be used for breeding purposes.

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AUTHOR CONTRIBUTIONS

J.A. – fieldwork, conceptualization, phenotypification, first manuscript draft and edition. Y.N. – Pollen study, manuscript contribution. A.R. – manuscript first draft and edition, fieldwork, interpretation of analytical data. L.S. – biochemical analysis. G.Z. – fieldwork. G.G. – phenotypification, conceptualization, fieldwork, manuscript contribution.

CONFLICT OF INTEREST

There are no conflicts of interest.

REFERENCES

- ALAJIL, O., SAGAR, V. R., KAUR, C., RUDRA, S. G., SHARMA, R. R., KAUSHIK, R., VERMA, M. K., TOMAR, M., AND KUMAR MEKHEMAR, M. (2021). Nutritional and phytochemical traits of apricots (*Prunus armeniaca* L.) for application in nutraceutical and health industry. *Foods*, 10, 1344, <https://doi.org/10.3390/foods10061344>.
- ASMA, B., AND OZTURK, K. (2005). Analysis of morphological, pomological and yield characteristics of some apricot germplasm in Turkey. *Genetic Resources and Crop Evolution*, 52, 305–313, <https://doi.org/10.1007/s10722-003-1384-5>.
- BORSANI, J., BUDDE, C. O., PORRINI, L., LAUXMANN, M. A., LOMBARDO, V. A., MURRAY, R., ANDREO, C. S., DRINCOVICH, M. F., AND LARA, M. V. (2009). Carbon metabolism of peach fruit after harvest: Changes in enzymes involved in organic acid and sugar level modifications. *Journal of Experimental Botany*, 60(6), 1823–1837, <https://doi.org/10.1093/jxb/erp055>.
- BOŽOVIĆ, D., BOSANČIĆ, B., VELIMIROVIĆ, A., ERCISLI, S., JAĆIMOVIĆ, V., AND KELES, H. (2017). Biological characteristics of some plum cultivars grown in Montenegro. *Acta Scientiarum Polonorum, Hortorum Cultus*, 16(2), 35–45, <https://doi.org/10.17660/ActaHortic.2012.968.8>.
- BUTKEVICIUTE, A., ABUKAUSKAS, V., JANULIS, V., AND KVIKLYS, D. (2022). Phenolic content and antioxidant activity in apples of the 'Galaval' cultivar grown on 17 different rootstocks. *Antioxidants*, 11(2), 266, <https://doi.org/10.3390/antiox11020266>.
- CARVALHO, L. C., GONÇALVES, E. F., SILVA, J. M., AND COSTA, J. M. (2021). Potential phenotyping methodologies to assess inter- and intravarietal variability and to select grapevine genotypes tolerant to abiotic stress. *Frontiers in Plant Sciences*, 12, 1–16, <https://doi.org/10.3389/fpls.2021.718202>.
- DJENIDI, H., KHENNOUF, S., AND BOUAZIZ, A. (2020). Antioxidant activity and phenolic content of commonly consumed fruits and vegetables in Algeria. *Progress in Nutrition*, 22, 224–235, <https://doi.org/10.23751/pn.v22i1.7701>.
- EHRHART, J. F. (1791). *Prunus dasycarpa* Ehrh. Beiträge zur Naturkunde, und den damit verwandten Wissenschaften, besonders der Botanik, Chemie, Haus- und Landwirtschaft, Arzneigelahrtheit und Apothekerkunst. *Hannover & Osnabrück*, 6, 90.
- EREMIN, G. V. (1985). *Remote hybridization of stone fruit plants*. Moscow, Russia: Agropromizdat.
- EREMIN, G. V. (2016). Pre-breeding in the selection of new varieties of stone fruit crops. *Selekcija I Sortovedenie Sadovyh Kul'tur*, 3, 48–52.
- EREMIN, G. V. (2018). Detection of genetic relations between species in the genus *Prunus* L. when using them in breeding of stone fruit crops. *Proceedings on Applied Botany, Genetics and Breeding*, 179(3), 250–258, <https://doi.org/10.30901/2227-8834-2018-3-250-258>.
- EREMIN, G., EREMIN, V., AND GASANOVA, T. (2021). The gene pool of the black apricot - *Prunus dasycarpa* Pers. and its use in stone fruit crops breeding. *BIO Web of Conferences*, 38, 00029, <https://doi.org/10.1051/bioconf/20213800029>.
- FIORANI, F., AND SCHURR, U. (2013). Future scenarios for plant phenotyping. *Annual Review of Plant Biology*, 64, 267–291, <https://doi.org/10.1146/annurev-arplant-050312-120137>.
- FORCADA, C. F. I., REIG, G., GIMENEZ, R., MIGNARD, P., MESTRE, L., AND MORENO, M. A. (2019). Sugars and organic acids profile and antioxidant compounds of nectarine fruits influenced by different rootstocks. *Scientia Horticulturae*, 248, 145–153, <https://doi.org/10.1016/j.scienta.2018.12.010>.
- FRATIANNI, F., D'ACIERNO, A., ALBANESE, D., DI MATTEO, M., COPPOLA, R., AND NAZZARO, F. (2022). Biochemical characterization of traditional varieties of apricots (*Prunus armeniaca* L.) of the Campania Region, Southern Italy. *Foods*, 11, 100–112, <https://doi.org/10.3390/foods11010100>.
- FRATIANNI, F., OMBRA, M. N., D'ACIERNO, A., CIPRIANO, L., AND NAZZARO, F. (2018). Apricots: Biochemistry and functional properties. *Current Opinion in Food Science*, 19, 23–29, <https://doi.org/10.1016/j.cofs.2017.12.006>.
- HAMBARSTUMYAN, M. A., ARUTYUNYAN, M. N., AND HAMBARSTUMYAN, A. M. (1977). Wild forms of apricot in Armenia. *Biological Journal of Armenia*, 30(2), 3–8.
- HARUTUNYAN, T. H. (2021). *Investments and investment activities*. Yerevan, Armenia: ANAU.
- KAFKALETOU, M., KALANTZIS, I., KARANTZI, A., CHRISTOPOULOS, M. V., AND TSANTILI, E. (2019). Phytochemical characterization in traditional and modern apricot (*Prunus armeniaca* L.) cultivars-nutritional value and its relation to origin. *Scientia Horticulturae*, 253, 195–202, <https://doi.org/10.1016/j.scienta.2019.04.032>.
- KHACHATRYAN, A. R. (2002). *Agronomic Research Methods. Educational Manual*. Yerevan, Armenia: Asoghik.
- KOSTINA, K. F. (1936). The Apricot. *Bulletin Applied Botany Genetics and Plant Breeding*, Suppl. 83. Institute of Plant Industry: Leningrad.
- KOSTINA, K. F. (1941). *Armeniaca*. In: V. L. Komarov (Ed.), *Flora of the U.S.S.R* (pp. 581–604). Moskva-Leningrad: Izdatel'stvo Akademii Nauk U.S.S.R.
- KOSTINA, K. F. (1964). Application the phytogeographical method to apricot classification. In *Proceedings of the Nikita Botanical Gardens*. Moscow: Kolos.

- KOSTINA, K. F., AND RYABOV, I. N. (1960). The results of the works of the state Nikitsky botanical garden in remote hybridization of southern fruit cultures. In *Remote Hybridization of Plants and Animals* (pp. 17–37). Moscow: Nauka.
- KOVALCHUK, I. Y., MUKHITDINOVA, Z., TURDIYEV, T., MADIYEVA, G., AKIN, M., EYDURAN, E., AND REED, B. M. (2017). Modeling some mineral nutrient requirements for micropropagated wild apricot shoot cultures. *Plant Cell, Tissue and Organ Culture (PCTOC)*, 129, 325–335.
- KOVALCHUK, I. Y., MUKHITDINOVA, Z., TURDIYEV, T., MADIYEVA, G., AKIN, M., EYDURAN, E., AND REED, B. M. (2018). Nitrogen ions and nitrogen ion proportions impact the growth of apricot (*Prunus armeniaca*) shoot cultures. *Plant Cell, Tissue and Organ Culture (PCTOC)*, 133, 263–273.
- MAMAJANYAN, S. A. (2018). *Methodology of Agronomic Research*. Yerevan, Armenia: Armenian National Agrarian University.
- MELQUMYAN, M. S. (2014). *Organization of entrepreneurial activity*. Yerevan, Armenia: Zangak.
- MICHURIN, I. V. (1908). Apricot 'Tlor-Tsiran'. *Bulletin of Horticulture, Fruit Growing and Olericulture*, 8, 345–348.
- MURATHAN, Z. T., ARSLAN, M., AND ERBIL, N. (2020). Analyzing biological properties of some plum genotypes grown in Turkey. *International Journal of Fruit Science*, 20(S3), 1729–1740, <https://doi.org/10.1080/15538362.2020.1830917>.
- NICOLÁS-ALMANSA, M., RUIZ, D., SALAZAR, J. A., GUEVARA, A., COS, J., MARTÍNEZ-GÓMEZ, P., AND RUBIO, M. (2023). Phenotypic and molecular characterization of new interspecific Japanese plum × apricot hybrids (plumcots). *Scientia Horticulturae*, 318, 112131, <http://doi.org/10.1016/j.scienta.2023.112131>.
- PAPIKHIN, R. V., PUGACHEVA, N. V., VASILIEVA, M. N., AND DUBROVSKY, M. L. (2011). Study of microsporogenesis of intergenetic, interspecific and intercultivar hybrids of seed and stone/fruit plants. *Plodovodstvo*, 23, 31–36.
- PETRUCCELL, R., BONETTI, A., CIACCHERI, L., IERI, F., GANINO, T., AND FARALONI, C. (2023). Evaluation of the fruit quality and phytochemical compounds in peach and nectarine cultivars. *Plants*, 12(8), 1618, <https://doi.org/10.3390/plants12081618>.
- SAEED, I., GUO, X., AZEEM, M., ELSHIKH, M. S., ZAINAB, B., AYAZ, Z., YOU, L., ALWAHIBI, M. S., AND ABBASI, M. A. (2021). Comparative assessment of polyphenolics' content, free radicals' scavenging and cellular antioxidant potential in apricot fruit. *Journal of King Saud University*, 33(5), 101459, <http://doi.org/10.1016/j.jksus.2021.101459>.
- SEDOV, E. N., AND OGOLTSOVA, T. P. (1999). *The program and methodology of variety studies of fruit, berry and nut-bearing crops* (608 p). Orel Russia: All-Russian Research Institute of Fruit Crop Breeding.
- SOLDATOV, I. V., AND SALAŠ, P. (2007). Hybridization of domestic prunes with black apricot (*Prunus domestica* L. × *Armeniaca dasycarpa* Ehrh.). *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 55(5), 147–154, <https://doi.org/10.11118/actaun200755050147>.
- SU, C., ZHENG, X., ZHANG, D., CHEN, Y., XIAO, J., HE, Y., HE, J., WANG, B., AND SHI, X. (2020). Investigation of sugars, organic acids, phenolic compounds, antioxidant activity and the aroma fingerprint of small white apricots grown in Xinjiang. *Journal of Food Science*, 85, 4300–4311, <https://doi.org/10.1111/1750-3841.15523>.
- TAREEN, A., PANEZAI, M. A., SAJJAD, A., ACHAKZAI, J. K., KAKAR, A. M., AND KHAN, N. Y. (2021). Comparative analysis of antioxidant activity, toxicity, and mineral composition of kernel and pomace of apricot (*Prunus armeniaca* L.) grown in Balochistan, Pakistan. *Saudi Journal of Biological Sciences*, 28(5), 2830–2839, <https://doi.org/10.1016/j.sjbs.2021.02.015>.
- TSATURYAN, A. (2021). *Theoretical and Applied basics of High-performance Liquid Chromatography*. Educational manual. Yerevan, Armenia: YSU Publishing House.
- ULIKHANYAN, G., GALSTYAN, H., DUMANYAN, K., BEGLARYAN, M., POGHOSYAN, G., SHEKOYAN, V., ANANIKYAN, H., ANANIKYAN, V., GOGINYAN, V., ULIKHANYAN, G., TASCHYAN, S., AND CHICHOYAN, N. (2022). The study of the biological activities of *Ziziphora clinopodioides*. *Brazilian Journal of Pharmaceutical Sciences*, 58, 1–18, <http://dx.doi.org/10.1590/s2175-97902022e19331>.
- UPOV (TG/70/5, proj.1). (2016). Guidelines for the Conduct of Tests for Distinctness, Uniformity and Stability.
- VERMISHYAN, A. M., DILANYAN, G. K. H., AND SANAGYAN, M. B. (1958). *Fruits of Armenia. Stone Fruits* (Vol. 1). Yerevan, Armenia: State Publishing House of Armenia.
- ZHOU, W., NIU, Y., DING, X., ZHAO, S., LIA, Y., FAN, G., ZHANG, S., AND LIAO, K. (2020). Analysis of carotenoid content and diversity in apricots (*Prunus armeniaca* L.) grown in China. *Food Chemistry*, 330, 127223, <https://doi.org/10.1016/j.foodchem.2020.127223>.

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