ACTA Acta Sci. Pol., Hortorum Cultus 13(5) 2014, 77-90

DETERMINATION OF SIZE AND SHAPE PROPERTIES OF APRICOTS USING MULTIVARIATE ANALYSIS

Tomo Milošević[1], Nebojša Milošević[2], Ivan Glišić[1], Ivana S. Glišić[2]
[1] Faculty of Agronomy in Čačak, Serbia
[2] Fruit Research Institute in Čačak, Serbia

Abstract. Fruit apricot dimensions, weight, size and shape are the most commonly measured pomological properties. The size and shape features of 13 apricot (*Prunus armeniaca* L.) cultivars and promising Serbian selections grown in Western Serbia were investigated using a multivariate analysis. The apricots promoted fruits wider than long in shape, except 'Harcot', 'T 7', 'Précoce de Tyrinthe', 'Roksana' and 'Vera', whereas all cultivars and selections are wider than thick. Most of cultivars and/or selections tend to round shape. Mean values for fruit and stone weight, flesh rate, geometric mean diameter, kernel weight, sphericity, aspect ratio, surface area and volume ranged from 37.09 to 81.60 g, 2.71 to 4.18 g, 91.93 to 96.46%, 41.76 to 65.08 mm, 0.60 to 1.17 g, 0.94 to 1.03, 95.04 to 108.09%, 55.13 to 133.77 cm^2 and 38.31 to 145.10 cm^3, respectively. For the most of attributes evaluated, 'Roksana' had the highest values. A high correlation was found among some physical attributes. According to their 22 properties, the apricots grouped into five clusters. There was either relative independence or close correspondence among the evaluation indexes of apricot fruit quality. Principal components analysis showed that the first three principal components variance accumulation contribution rate amounted to 85.77%, which reflected most of the size and shape characteristics of apricots.

Key words: fruit pomological properties, cluster analysis, elongation, principal component analysis, *Prunus armeniaca* L.

INTRODUCTION

The apricot (*Prunus armeniaca* L.) is considered to be among the most delectable and consumable of all fruits. Fruit are used in fresh and dry form, canned or preserved as jam, marmalade or pulp [Mirzaee et al. 2009]. Brandies and wines are made from both cultivated and non-domesticated apricot both in Europe and Asia [Genovese et al. 2004]. Also, apricot kernels are used in the production of oils, benzaldehyde, cosmetics,

Corresponding author: Tomo Milošević, Department of Fruit Growing and Viticulture, Faculty of Agronomy, 32000 Čačak, Cara Dušana 34, Serbia, e-mail: tomomilosevic@kg.ac.rs

active carbon, and aroma perfume, whereas pits, beside others, can be used as an important source of energy [Mandal et al. 2007].

In past few decades, apricot production and processing required new management practices. For example, total mechanization, from planting to harvesting, characterizes the high-density apricot culture. This new cropping system represents the real challenge for innovation and profitability of the sector; it is based on ≥ 1000 plants per hectare, central leader-shaped trees [Milošević et al. 2011], and a new generation of over-the-row continuous harvesting machines adapted from those already used for grape [Camposeo et al. 2008]. Additionally, for apricot postharvest operations were also required specific equipments and machines [Erdogan et al. 2003, Hacisefroğullari et al. 2007]. From this point, the knowledge of physical properties of biomaterials, including apricot fruits, are important in providing essential engineering data required for design and development of machines, structures and equipment for handling, processing, transporting and storage of food materials. Shape and size are relevant in designing equipment for grading, sorting, cleaning and packaging of apricots [Janatizadeh et al. 2008]. Apricots are distinguishable by fruit properties and fruit dimensions, with size, fruit weight, skin colour and shape being the most important parameters [Ruiz and Egea 2008].

Fruit size and shape impact market value and are important physical attributes in sorting, sizing, packaging and transportation of fruits, and designing relevant equipment [Erdogan et al. 2003]. Fruit weight, fruit dimensions and shape can be determined with standard laboratory equipment such as digital balance and calipers; however multivariate analysis and the other techniques gained more importance. Recently, several researchers have studied on morphological or fruit size and shape analysis of different apricot selections by using these methods [Ruiz and Egea 2008, Mratinić et al. 2011, Yilmaz et al. 2012]. From these purposes, the objective of this study was to determine the size and shape properties of seven cultivars and six promising Serbian apricot selections using a multivariate analysis.

MATERIAL AND METHODS

Plant material, experimental procedure and analysis of fruit and stone properties. The experiment was conducted in private orchard in village Prislonica (43°57'N, 20°26'E), in the Region of Cacak (Western Serbia), situated at 340 m altitude, as previously reported [Milošević et al. 2012]. The trees, spaced at 5.5 m × 3.0 m, were planted in 2008. Standard cultural practices were applied, except irrigation.

The study lasted two years (2011 and 2012). Seven apricot cultivars ('Aleksandar', 'Biljana', 'Vera', 'Harcot', 'Kecskemét Rosè', 'Précoce de Tyrinthe' and 'Roksana') and six promising Serbian selections ('T 13-01', 'T 1-1', 'T 7', 'T 12', 'T 14' and 'T 18'), grafted on Myrobalan seedlings, were used as a plant material. The 25 fully ripening fruits in four replicates of each cultivar and/or selection were tested.

Three fruit and stone linear dimensions namely as length (mm), width (mm) and thickness (mm) were measured with caliper Starrett 727 (Athol, MA, USA). Fruit and stone weight (g) were measured by digital balance FCB 6K (Kern & Sohn GmbH, Belingen, Germany). Fruit weight/stone weight ratio or flesh rate (%) was also evaluated.

For kernel analysis, the pits were cracked by hand. After cracking, kernel weight (g) was measured.

The percent kernel was calculated by the following relationship [Ozkan and Koyncu 2005]:

$$PK = \frac{KW}{SW} \cdot 100 \tag{1}$$

where: PK – percent kernel (%), KW – kernel weight (g), SW – stone weight (%).

The taste of kernels was evaluated organoleptically by a group of panelists selected for this study and indexed with values from IBPGRI [1984].

Fruit shape index was calculated with the following equation [Mohsenin 1980]:

$$SI = \frac{W + T}{2L} \tag{2}$$

where: SI – shape index, L – length, W – weight, T – thickness.

Elongation was calculated by using the following relationship [Fıratlıgil-Durmuş et al. 2010]:

$$E = \frac{\text{Major axis lenght}}{\text{Minor axis lenght}} \tag{3}$$

where: E – elongation.

Following the terminology proposed by Caillavet and Souty [1950], polar (L), suture (W) and equatorial (T) diameters were measured and then transformed to the parameter denominated "size" or arithmetic mean diameter defined as:

$$D_a = \frac{L + W + T}{3} \tag{4}$$

where: D_a – arithmetic mean diameter (mm).

Geometric mean diameter, equivalent diameter, square mean diameter and spericity were defined by using the following equations [Mohsenin 1980]:

$$D_g = \sqrt[3]{LWT} \tag{5}$$

where: D_g – geometric mean diameter (mm),

$$D_e = \left(\frac{L(W + T)^2}{4} \right)^{\frac{1}{3}} \tag{6}$$

where: D_e – equivalent diameter (mm),

$$S_e = \left(\frac{(L \cdot W) + (L \cdot T) + (W \cdot T)}{3} \right)^{\frac{1}{2}} \tag{7}$$

where: S_e – square mean diameter (mm),

$$\varphi = \frac{D_g}{L} \tag{8}$$

where: φ – sphericity,

The aspect ratio was calculated [Altuntaş et al. 2005] as:

$$R_a = \frac{W}{L} \cdot 100 \tag{9}$$

where: R_a – aspect ratio (%).

The surface area was calculated from the equation given by McCabe et al. [1986] as:

$$S = \pi D_g^2 \tag{10}$$

where: S – surface area (cm^2).

The fruit volume was calculated according to Jain and Bal [1997]:

$$V = \frac{\pi LWT}{6} \tag{11}$$

where: V – fruit volume (cm^3).

Data analysis. Analysis of variance (ANOVA) and Pearson's correlation coefficients were carried out using Microsoft Excel software (Microsoft Corporation, Roselle, IL, USA). Fisher's least significant difference (*LSD*) test was used to calculate the means with 95% ($P \leq 0.05$) confidence. Clustering of selections into similarity groups was done using the method of UPGA (Unweighted Pair Group Average) with SPSS 8.0 (SPSS, Inc., Chicago, USA). Principal component analysis (PCA) was performed to evaluate relationships among variables and any possible cultivar groupings based on similar properties by using an XLSTAT procedure (XLSTAT 7.5, Addinsoft, USA). All data are mean values for 2011 and 2012, due to differences between years were not significant.

RESULTS AND DISCUSSION

Fruit pomological properties. Data present in Table 1 showed that fruit linear dimensions, SI and E significantly varied among apricots. The highest L, W, T and E values were found in 'Roksana'. 'K. Rosè' is the cultivar with the lowest all fruit dimensions. Statistically similar L and W values as compared to 'K. Rosè' were found in 'T 13-01' and 'Harcot', respectively, whereas the lowest E had 'T 14'. Selection 'T 13-01' had the highest SI value, and 'Roksana' had the lowest. Generally, our range of fruit dimensions for some apricots were much higher then those for a group of Turkish [Erdogan et al. 2003] and Iranian cultivars [Jannatizadeh et al. 2008, Mirzaee et al. 2009]. For example, in respect to design a mechanism for mechanical harvesting of 'Hacthaliloğlu' apricot cultivar, Erodgan et al. [2003] reported ideal L, W and T of the fruit as 40.92, 38.94 and 35.21 mm, respectively. These differences may be caused by variation in cultivar or origin. Generally, fruit dimensions are important in determining aperture size of machines, particularly in separation of materials, and these dimensions may be useful in estimating the size of machine components and parameters [Mohsenin 1980].

In literature SI of fruits of different apricot cultivars were reported between 1.02 and 1.09 [Abd El-Rzek et al. 2011] or 1.05 and 1.20 [Dumitru et al. 2011].

Table 1. Fruit linear dimensions, shape index and elongation of apricots

Genotype	Length (mm)	Width (mm)	Thickness (mm)	Shape index	Elongation
Aleksandar	48.12 ±0.68 f	51.53 ±0.65 bcd	46.58 ±0.68 g	1.02 ±0.01 ab	1.03 ±0.01 fgh
Biljana	49.74 ±1.11de	51.05 ±1.04 cd	48.15 ±0.95 de	1.00 ±0.01 bc	1.02± 0.01 gh
T 13-01	42.38 ±0.61g	45.81 ±0.78 f	42.39 ±0.62 i	1.04 ±0.01 a	1.04 ±0.01 fgh
Harcot	47.18 ±0.91f	44.78 ±0.59 g	42.41 ±0.52 i	0.92 ±0.01gh	1.11 ±0.01 bc
T 1-1	47.78 ±0.54 f	48.99 ±0.69 e	46.14 ±0.46 h	0.99 ±0.01 bcd	1.03 ±0.01 fgh
T 7	52.84 ±1.05 b	51.48 ±1.26 bcd	49.66 ±0.95 b	0.96 ±0.01 def	1.06 ±0.01 def
T 12	50.92 ±0.88 cd	51.64 ±0.90 bcd	47.36 ±0.74 f	0.97 ±0.01 cdf	1.08 ±0.01 cde
T 14	48.62 ±0.67 ef	50.71 ±0.74 d	48.05 ±0.89 e	1.02 ±0.01 ab	1.01 ±0.02 h
T 18	47.79 ±0.79 f	48.46 ±0.73 e	45.67 ±0.64 h	0.98 ±0.01 cde	1.05 ±0.01 efg
K. Rosè	43.57 ±0.90 g	43.92 ±0.74 g	38.10 ±0.53 j	0.94 ±0.02 fgh	1.14 ±0.02 ab
P. Tyrinthe	52.85 ±0.75 b	51.91 ±0.66 bc	48.43 ±0.42 d	0.95 ±0.01 efg	1.09 ±0.01 cd
Roksana	69.28 ±1.33 a	66.11 ±1.07 a	60.23 ±0.82 a	0.91 ±0.01 h	1.15 ±0.01 a
Vera	52.57 ±0.91 bc	52.30 ±0.56 b	48.83 ±0.66 c	0.96 ±0.01 def	1.08 ±0.02 cde

Means followed by different letter in the column are different as determined by the LSD test at $P \leq 0.05$

From this point, if SI values are around 1 fruit tend to round shape, while if these values are higher than 1, fruits correspond to ovoid shape. According to data for elongation index, it could be said that 'Roksana' and 'T 14' had high and low elongated fruits, respectively. Data from other collections around the world suggested that elongation depend on cultivar and fruit orientations in vacancy [Ercisli et al. 2012].

As seen in Table 2, fruit weight (FW) and stone weight (SW), flesh rate (FR) and stone axial dimensions considered in the present work were found to be statistically significant. The highest FW and stone length was found for 'Roksana', and SW for 'Vera' and 'T 14', with no significant differences between them.

Table 2. Fruit and stone weight, flesh rate and stone linear dimensions of apricots

Genotype	Fruit weight (g)	Stone weight (g)	Flesh rate (%)	Stone length (mm)	Stone width (mm)	Stone thick-ness (mm)
Aleksandar	66.40 ±2.20 cd	2.86 ±0.07 e	95.66 ±0.16 b	27.27 ± 0.48 cd	21.69 ± 1.10 bc	11.41 ± 0.19 f
Biljana	68.70 ±2.67 c	3.59 ±0.16 b	94.67 ±0.37 def	29.09 ±0.60 b	24.52 ±0.44 a	13.13 ±0.51 a
T 13-01	49.27 ±1.85 f	2.92 ±0.09 de	93.98 ±0.35 g	24.51 ±0.36 e	21.15 ±0.39 c	12.03 ±0.30 e
Harcot	50.08 ±1.76 f	2.73 ±0.06 e	94.47 ±0.29 efg	24.69 ±0.22 e	19.55 ±0.12 d	12.61 ±0.15 cd
T 1-1	63.00 ±1.32 d	3.17 ±0.08 cd	94.93 ±0.22 cde	27.02 ±0.39 cd	24.15 ±0.27 a	12.26 ±0.18 e
T 7	76.89 ± 4.42 ab	3.72 ±0.17 b	95.05 ±0.29 bcd	28.46 ±0.33 b	24.09 ±0.30 a	12.65 ±0.47 cd
T 12	70.00 ±3.33 c	3.28 ±0.11 c	95.20 ±0.30 bcd	28.57 ±0.61 b	24.20 ±0.59 a	12.33 ±0.29 de
T 14	67.56 ±2.13 c	4.18 ±0.14 a	95.20 ±0.32 bcd	27.40 ±0.20 c	24.21 ±0.20 a	12.24 ±0.34 e
T 18	57.10 ±2.41 e	3.81 ±0.10 b	93.20 ±0.37 h	27.03 ±0.49 cd	22.67 ±0.50 b	11.48 ±0.23 f
K. Rosè	37.09 ±1.40 g	2.94 ±0.09 de	91.93 ±0.48 i	26.83 ±0.49 d	22.45 ±0.45 b	11.64 ±0.21 f
P. Tyrinthe	77.34 ±2.19 ab	2.71 ±0.15 e	96.46 ±0.22 a	28.17 ±0.54 b	24.01 ± 0.29 a	13.25 ±0.18 a
Roksana	81.60 ±2.32 a	3.82 ±0.14 b	95.29 ±0.20 bc	30.31 ±0.32 a	24.36 ±0.32 a	12.72 ±0.41 bc
Vera	76.09 ±2.21 b	4.33 ±0.20 a	94.27 ±0.32 fg	28.52 ±0.43 b	24.36 ±0.30 a	13.01 ±0.37 ab

Means followed by different letter in the column are different as determined by the LSD test at $P \leq 0.05$

The lowest FW had K. Rosè. The highest SW was found in 'Vera' and 'T 14', and the lowest and similar in 'Aleksandar', 'Harcot' and 'P. Tyrinthe', respectively. However, 'P. Tyrinthe' had the best FR, whereas the poorest registered in 'K. Rosè'. Generally, 'Harcot' is the cultivar with the lowest stone lenght and width. Over 61.5% apricots had higher and similar stone width as compared to others. Stone thickness is the highest in 'P. Tyrinthe' and 'Biljana', and the lowest in 'K. Rosè' and 'T 18'. Previous study on apricot also reported high variability among apricots regarding above fruit characteristics [Mirzaee et al. 2009, Milošević et al. 2010, 2011, 2012]. For example, flesh rate varied between 90.1 to 95.1% [Vachůn 2003]. Above properties may be useful in the separation and transportation of the fruit by hydrodynamic means in water canals, design a mechanism for mechanical harvesting and other processes related to apricot fruits [Jannatizadeh et al. 2008].

The KW and PK significantly varied among cultivars and/or selections (tab. 3). The highest KW produced by 'Vera', 'T 7' and 'T 14', whereas the lowest produced by 'Aleksandar' and 'T 1-1'. Moreover, 'P. Tyrinthe' and 'T 18' had higher and lower PK, respectively. All cultivars and selections, except 'K. Rosè', had sweet kernels. Kernels of 'K. Rosè' are strong bitter in taste which is due to the presence of a cyanogenic glycoside amygdalin [Montgomery 1969]. It is a well-known fact that apricot kernels had a high utilization value [Mandal et al. 2007].

Table 3. Kernel weight, percent kernel and kernel taste of apricots

Genotype	Kernel weight (g)	Percent kernel (%)	Kernel taste*
Aleksandar	0.62 ±0.02 g	21.87 ±0.78 ef	1
Biljana	0.69 ±0.04 efg	19.39 ±1.44 fg	1
T 13-01	0.90 ±0.03 cd	31.11 ±1.42 b	1
Harcot	0.75 ±0.02 ef	27.74 ±1.39 c	1
T 1-1	0.60 ±0.02 g	19.06 ±0.69 fg	1
T 7	1.13 ±0.04 a	31.17 ±2.05 b	1
T 12	0.76 ±0.03 ef	23.51 ±1.49 de	1
T 14	1.09 ±0.03 a	26.33 ±0.95 cd	1
T 18	0.67 ±0.02 fg	17.76 ±0.77 g	1
K. Rosè	0.81 ±0.05 de	28.11 ±2.24 bc	3
P. Tyrinthe	0.95 ±0.04 bc	36.32 ±2.98 a	1
Roksana	1.07 ±0.04 ab	28.46 ±1.62 bc	1
Vera	1.17 ±0.04 a	27.30 ±1.35 c	1

Means followed by different letter in the column are different as determined by the LSD test at $P \leq 0.05$
*Kernel taste 1 = sweet; 2 = weak bitterness; 3 = strong bitterness [IBPGRI 1984]

Data presented in Table 4 recorded that D_a, D_g, D_e and S_e significantly varied among apricots. The greatest all above values were found for Roksana, and the lowest for K. Rosè. Jannatizadeh et al. [2008] found D_g values between 37.35 and 47.01 mm for six Iranian apricot cultivars, respectively. In another study, three Iranian apricots produced fruits with D_g between 34.89 and 44.09 mm, respectively [Mirzaee et al. 2009]. The differences between our results and those of above authors could be due to the different eco-geographical groups of cultivars studied. Interestingly, for same selections, values for D_a, D_g, D_e and S_e were very similar or identical. Similar conclusion was obtained by Ehiem and Simonyan [2012] for wild mango selections. In general, the knowledge related to all these diameters would be valuable in designing the grading process.

The mean values and ranges of φ, Ra, S and V are presented in tab. 5. The fruit shape is determined in terms of its φ and Ra. According to the results, the highest values of φ were found for 'T 13-01' and the lowest for 'Roksana'. The R_a was the highest for 'Aleksandar' and 'T 13-01' and the lowest also for 'Roksana'.

Jannatizadeh et al. [2008] and Mirzaee et al. [2009] found that φ for Iranian apricots varied between 0.875 to 0.973 or 0.84 to 0.94, whereas Mratinić et al. [2011] found φ and R_a values between 0.91 and 1.02, and 92.76 and 103.66% for Macedonian apricot genotypes.

In general, φ is an expression of the shape of a solid related to that of a sphere of the same volume while the R_a relates the width to the length of the fruit, being the indicative of its tendency toward its oblong shape [Altuntaş et al. 2005]. Contrary to φ and R_a, fruits of 'Roksana' had the highest values of S and V, whereas the lowest were found in 'K. Rosè'. In comparison with previous studies, average S values of different apricot cultivars were between 2646.27 and 5351.69 mm^2 for Turkish apricot cultivars [Hacisefroğullari et al. 2007], and/or between 4395.25 and 6458.35 mm^2 for Iranian apricot cultivars [Jannatizadeh et al. 2008]. The S and V may be important for apricot drying, especially in the drying equipment simulation models for apricot [Mirzaee et al. 2008]. Regarding V, it may be concluded that large number of 'K. Rosè' fruits could be packed in the predetermined volume compared with the other cultivars [Jain and Bal 1997].

Table 4. Arithmetic and geometric mean diameter, equivalent diameter and square mean diameter of apricots

Genotype	Arithmetic mean diameter (mm)	Geometric mean diameter (mm)	Equivalent diameter (mm)	Square mean diameter (mm)
Aleksandar	48.74 ±0.62 de	48.69 ±0.62 de	48.72 ±0.62 de	48.72 ±0.62 de
Biljana	49.65 ±0.97 d	49.62 ±0.97 d	49.63 ±0.97 d	49.63 ±0.97 d
T 13-01	43.53 ±0.63 g	43.49 ±0.62 g	43.51 ±0.63 g	43.51 ±0.63 g
Harcot	44.79 ±0.64 g	44.74 ±0.63 g	44.76 ±0.63 g	44.76 ±0.63 g
T 1-1	47.64 ±0.46 ef	47.61 ±0.46 ef	47.62 ±0.46 ef	47.62 ±0.46 ef
T 7	51.33 ±1.02 b	51.30 ±1.02 b	51.31 ±1.02 b	51.31 ±1.02 b
T 12	49.97 ±0.78 cd	49.93 ±0.77 cd	49.95 ±0.78 cd	49.95 ±0.78 cd
T 14	49.13 ±0.53 d	49.08 ±0.53 d	49.10 ±0.53 d	49.10 ±0.53 d
T 18	47.31 ±0.63 f	47.28 ±0.63 f	47.29 ±0.63 f	47.29 ±0.63 f
K. Rosè	41.86 ±0.59 h	41.76 ±0.58 h	41.81 ±0.59 h	41.81 ±0.59 h
P. Tyrinthe	51.06 ±0.54 bc	51.02 ±0.54 bc	51.04 ±0.54 bc	51.04 ±0.54 bc
Roksana	65.21 ±0.97 a	65.08 ±0.95 a	65.14 ±0.96 a	65.14 ±0.96 a
Vera	51.23 ±0.62 bc	51.19 ±0.63 bc	51.21 ±0.62 bc	51.21 ±0.62 bc

Means followed by different letter in the column are different as determined by the LSD test at $P \leq 0.05$

Table 5. Sphericity, aspect ratio, surface area and fruit volume of apricots

Genotype	Sphericity	Aspect ratio (mm)	Surface area (cm^2)	Volume (cm^3)
Aleksandar	1.01 ±0.00 ab	107.16 ±1.13 a	74.71 ±1.87 ef	60.68 ±2.25 ef
Biljana	1.00 ±0.00 bc	102.72 ±0.97 bc	77.66 ±3.01 de	64.60 ±3.73 de
T 13-01	1.03 ±0.01 a	108.09 ±0.94 a	59.60 ±1.71 h	43.29 ±1.83 i
Harcot	0.95 ±0.01 fg	95.04 ±0.92 f	63.11 ±1.75 h	47.12 ±1.90 h
T 1-1	1.00 ±0.01 bc	102.57 ±1.26 bc	71.31 ±1.39 fg	56.62 ±1.65 fg
T 7	0.97 ±0.00 def	97.37 ±0.89 ef	83.02 ±3.32 b	71.40 ±4.30 b
T 12	0.98 ±0.01 cde	101.48 ±1.26 bcd	78.59 ±2.44 cd	65.56 ±3.03 cd
T 14	1.01 ±0.01 ab	104.47 ±2.04 b	75.86 ±1.62 de	62.08 ±1.97 de
T 18	0.99 ±0.01 bcd	101.51 ±1.45 bcd	70.38 ±1.90 g	55.58 ±2.28 g
K. Rosè	0.96 ±0.01 efg	101.09 ±2.20 cd	55.13 ±1.56 i	38.31 ±1.62 j
P. Tyrinthe	0.97 ±0.00 def	98.29 ±1.10 def	81.96 ±1.74b c	69.71 ±2.20 bc
Roksana	0.94 ±0.01 g	95.53 ±1.22 f	133.77 ±4.02 a	145.10 ±6.55 a
Vera	0.97 ±0.01 def	99.65 ±1.38 cde	82.53 ±1.99 b	70.48 ±2.54 b

Means followed by different letter in the column are different as determined by the LSD test at $P \leq 0.05$

Relationship among fruit physical attributes. Significant correlations were observed among main fruit and stone physical attributes (tab. 6). The fruit L was highly correlated with the other two fruit dimensions, whereas all three dimensions significantly correlated with FW; this result showed that the FW of apricot related to L, W and T [Mratinić et al. 2011].

Table 6. Correlation matrix among main fruit pomological properties of different apricots

Variable	L	W	T	FW	SW	FR	KW	PK	D_g	φ	R_a	S	V
L	1	**0.961**	**0.944**	**0.756**	0.398	0.481	0.457	0.187	**0.984**	**-0.587**	**-0.589**	**0.988**	**0.985**
W		1	**0.973**	**0.795**	0.436	0.512	0.406	0.095	**0.990**	-0.361	-0.343	**0.989**	**0.982**
T			1	**0.870**	0.511	**0.567**	0.447	0.076	**0.984**	-0.318	-0.379	**0.971**	**0.954**
FW				1	0.477	**0.745**	0.467	0.128	**0.816**	-0.185	-0.298	**0.769**	**0.721**
SW					1	-0.195	**0.558**	-0.162	0.451	-0.048	-0.103	0.428	0.404
FR						1	0.040	0.160	0.526	-0.056	-0.181	0.485	0.446
KW							1	**0.691**	0.443	-0.286	-0.347	0.440	0.433
PK								1	0.125	-0.314	-0.319	0.140	0.149
D_g									1	-0.439	-0.453	**0.997**	**0.988**
φ										1	**0.934**	-0.463	-0.478
R_a											1	-0.462	-0.466
S												1	**0.997**
V													1

For abbreviation see section "Material and Methods"
In bold, significant values (except diagonal) at the level of significance $P = 0.05$

High and positive correlation between FR and T or FW indicated that FR mostly related to T or FW than L and W. These findings are parallel to the results of Karababa and Coşkuner [2013]. However, there was no relationship between SW and FW, fruit dimensions or FR. This may be due more to smaller variations in stone weights of the cultivars and selections to variations in FW or dimensions. These results are similar with the data of Yilmaz et al. [2012]. Contrary, high correlation was observed between SW and KW and between KW and PK. These findings are in harmony with the earlier results obtained on apricot [Kumar and Bhan 2010]. The D_a, S and V highly and positively correlated with fruit dimensions or FW, which composes the apricot size. These correlations illustrated that the D_g was found the best dimensional parameter for estimation of FW [Mohsenin 1980], and can be used to predict each other [Jannatizadeh et al. 2008]. Moreover, the R_a and φ negatively correlated with fruit L, reflects the importance of fruit L in determining fruit shape in general. Also, positive correlation existed between V and S, indicating that cultivars with high S tend to high fruit volume. These relationships may be useful and applicable [Marvin et al. 1987].

Cluster and principal component analysis. On the basis of data presented in fig. 1 it could be said that UPGA separates apricot selections into five main groups. The first group is consisted of 'Roksana' which is found to be most far from all other cultivars and selections. This cultivar had the best values of most attributes evaluated.

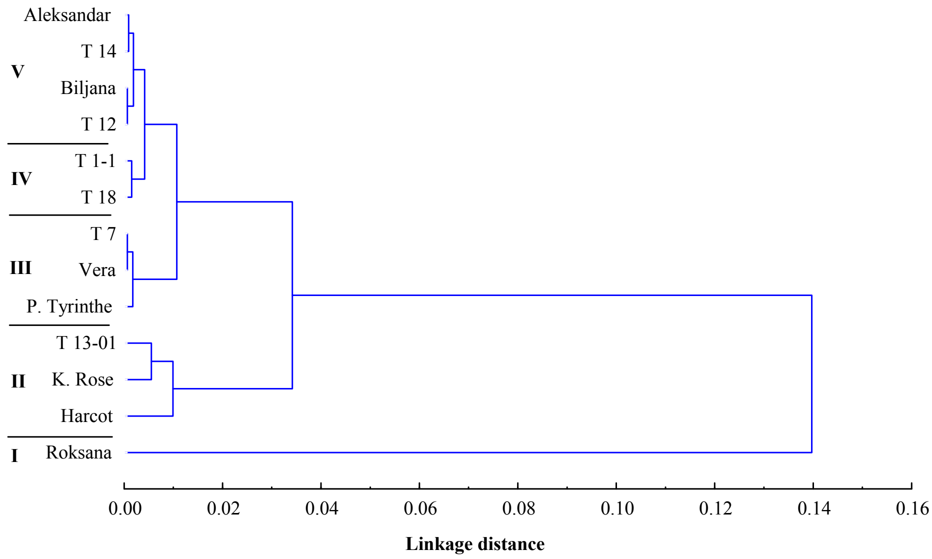

Fig. 1. UPGA cluster analysis for the apricot cultivars and promising selections analyzed for 21 physical and 1 sensorial properties of fruits and stones

Table 7. Eigenvalues and proportion of total variability, eigenvectors of the first three principal components (PC), and component scores for 13 apricots

Variable	Component loadings			Selection	Component scores		
	PC1 λ = 60.2	PC2 λ = 14.6	PC3 λ = 10.9		PC1	PC2	PC3
Length	0.985	-0.033	-0.072	Aleksandar	-0.994	2.084	-1.316
Weight	0.959	0.206	-0.017	Biljana	-0.127	1.321	-0.161
Thickness	0.969	0.231	0.021	T 13-01	-3.323	0.425	0.599
Fruit weight	0.845	0.265	-0.011	Harcot	-1.810	-2.338	-1.473
Stone weight	0.469	0.190	0.793	T 1-1	-1.344	1.823	-0.961
Flesh rate	0.536	0.263	-0.598	T 7	1.815	-1.079	0.584
Kernel weight	0.547	-0.414	0.583	T 12	0.262	0.539	-0.729
Percent kernel	0.232	-0.681	0.049	T 14	-0.066	0.717	2.289
D_g^*	0.985	0.126	-0.027	T 18	-1.440	0.723	0.716
Sphericity	-0.517	0.707	0.210	K. Rosè	-3.841	-2.322	0.494
Aspect ratio	-0.552	0.676	0.206	P. Tyrinthe	1.476	-1.163	-1.694
Surface area	0.978	0.093	-0.028	Roksana	7.715	-0.199	-0.223
Fruit volume	0.966	0.067	-0.030	Vera	1.675	-0.532	1.874
				Eigenvalue	7.832	1.894	1.424
				Variance (%)	60.249	14.569	10.953
				Cumulative	60.249	74.817	85.770

* D_g – geometric mean diameter

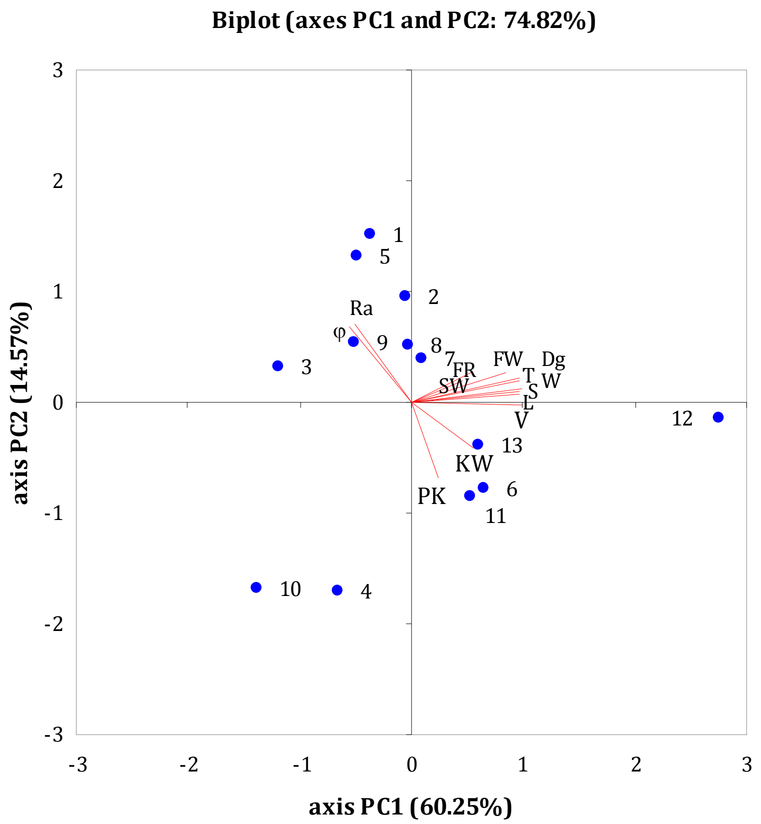

Fig. 2. Biplot based on PC analysis for fruit physical and sensorial attributes in 13 apricot cultivars and promising selections. For abbreviations see section "Materials and Methods". Numbers in biplot plane represent: 1, 'Aleksandar'; 2, 'Biljana'; 3. 'T 13-01'; 4. 'Harcot'; 5, 'T 1-1'; 6, 'T 7'; 7, 'T 12'; 8, 'T 14'; 9, 'T 18'; 10, 'K. Rosè'; 11, 'P. Tyrinthe'; 12, 'Roksana'; 13, 'Vera'

The second group includes three genotypes ('T 13-01', 'K. Rosè' and 'Harcot') which had the smallest FW and SW, fruit and stone dimensions, D_a, D_g, D_e and S_e, S and V. Genotypes such as 'T 7', 'Vera' and 'P. Tyrinthe' compose the third group, and these genotypes had the highest FW and KW and PK. Also, they had the highest values for all diameters. The fourth group is consisted of selections 'T 1-1' and 'T 18' which had the smallest KW and PK, and smaller values for all diameters. Finally, the fifth group includes four genotypes ('Aleksandar', 'T 14', 'Biljana' and 'T 12'), and they characterized with higher SI, E, φ and R_a values, respectively.

PCA reveals that first three components represent 85.77% of the total variability among apricots. PC1, PC2 and PC3 accounted for 60.25, 14.57 and 10.95% respectively (tab. 7). Positive values for PC1 showed that 'Roksana' had the highest fruit dimensions, FW, D_g, S and V values (fig. 2). Contrary, negative values for PC1 indicted that 'T 13-01', 'T 8' and 'K. Rosè' had the smallest values of above properties. PC2 indicates higher values for φ and R_a, and smaller values for PK which was represented with 'Aleksandar', 'Biljana', 'T 1-1' and 'Harcot'. The SW and KW were highly correlating variables with PC3. Positive values for PC3 showed that highest SW and KW had 'T 7', 'T 14' and 'Vera', while negative values for PC3 indicates that selections 'T 12' and 'P. Tyrinthe' had the smallest FR.

CONCLUSIONS

1. A high variability has been observed in the set of apricot selections evaluated with regard to the properties evaluated related to fruit size and shape, and significant differences among selections were observed for all physical attributes.

2. The cultivar that produced fruits with the greatest most of values was 'Roksana', while 'K. Rosè' produced the lowest, in general. Considering the values of the shape index, 'Roksana', 'K. Rosè' and 'Harcot' produced ovate fruits in general, while the others produced round. Cluster and principal component analysis showed that physical attributes evaluated were important in distinguishing the apricot cultivars and/or selections in terms of the dimensional properties.

3. The size and shape properties obtained in this study for the 13 apricots can be used to distinguish cultivars and selections from each other and also determine the parameters for handling, sorting and post-harvest processing that should be incorporated in the equipments and machines design.

ACKNOWLEDGEMENTS

This work was part of a research project TR 31064 funded by the Republic of Serbia, Ministry Education, Science and Technological Development. Special thanks to anonymous reviewers for very valuable comments on this study and Ms. Aleksandra Milošević for technical support.

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USTALENIE WŁAŚCIWOŚCI ROZMIARU I KSZTAŁTU MORELI PRZY UŻYCIU ANALIZY WIELOCZYNNIKOWEJ

Streszczenie. Wymiary owoców moreli, ich masa, rozmiar i kształt to najczęściej mierzone właściwości pomologiczne. Przy użyciu analizy wieloczynnikowej zbadano rozmiar i kształt owoców 13 odmian moreli (*Prunus armeniaca* L.) oraz obiecujących serbskich selekcji hodowanych w zachodniej Serbii. Z wyjątkiem odmian Harcot, T 7, Précoce de Tyrinthe, Roksana oraz Vera, owoce morele były szersze niż dłuższe, natomiast u wszystkich odmian i selekcji były szersze niż grubsze. Większość owoców odmian i/lub selekcji miała okrągły kształt. Średnia masa owocu i pestki, wskaźnik miąższu, średnia geometryczna średnica, masa jądra, sferyczność, format obrazu, powierzchnia oraz objętość wahały się odpowiednio: 37,09–81,60 g, 2,71–4,18 g, 91,93–96,46%, 41,76–65,08 mm, 0,60–1,17 g, 0,94–1,03, 95,04–108,09%, 55,13–133,77 cm^2 oraz 38,31–145,10 cm^3. Pod względem wszystkich ocenianych cech najwyższe noty uzyskała ‘Roksana’. Stwierdzono wysoką korelację między niektórymi cechami fizycznymi. Według 22 właściwości wyróżniono pięć grup. Zaobserwowano albo względną niezależność, albo ścisłą korelację między wskaźnikami oceny jakości owoców.

Słowa kluczowe: pomologiczne cechy owoców, analiza skupień, wydłużenie, analiza głównych składowych, *Prunus armeniaca* L.

Accepted for print: 4.06.2014