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DETERMINATION OF SHAPE IN FRUITS OF CHERRY LAUREL (*Prunus laurocerasus*) ACCESSIONS BY USING ELLIPTIC FOURIER ANALYSIS

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Abstract. Cherry laurel (*Prunus laurocerasus*) is an important wild edible fruits naturally grown in black sea region in Turkey. Shape attributes of twenty-one cherry laurel accessions were determined both descriptively and based on elliptic Fourier analysis first time in the literature. In the semantic evaluation, shape of most of the accessions was near to sphere. But, the results of the descriptive data showed that the accessions had different size, shape and gravimetric attributes. The accessions such as 30023, 30024 and 30027 had the highest means as to the gravimetric and size attributes, while the means of the 20043, 30028 and 30030 accessions were found to be the lowest. The sphericity data of 30019, 30028, 30030 and 30033 accessions had the highest means ranged between 96.2 and 97.8%. The cluster test divided the accessions to five subclasses. The genotypes in the 5th cluster had the highest gravimetric and size attributes than the other accessions. While the accessions in the 1st cluster were the highest sphericity mean, they had the lowest gravimetric and size attributes.

Key words: Cherry laurel, elliptic Fourier, *Prunus laurocerasus*, shape, size

INTRODUCTION

Turkey is rich in particular for deciduous fruit species and availability of different agro-climatic zone within the country promote to grow lots of fruit species. Each agro-climatic regions in Turkey has also special wild edible fruit species [Ercisli 2004].

Cherry laurel (*Prunus laurocerasus* L.) is one of the most desirable wild edible fruits that grown only in Black Sea region in Turkey and more recently the interest to this bright red and black colored cherry laurel fruits increased because of the popularization

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of healthy properties of this unique fruit [Halilova and Ercisli 2010, Orhan and Akkol 2011, Yildiz et al. 2014]. In particular East Black Sea region has numerous unnamed cherry laurel accessions that abundantly growing as solitary trees and they do not sprayed with pesticides because cherry laurel fruit is high resistance to pest and diseases. Thus they are very suitable fruit for organic production as well [Akbulut et al. 2007]. Local communities of the region practice their traditional knowledge on cultivation, harvesting and processing of this fruit. They have been grown and selected over many centuries to meet the requirements of the farmer in the region and almost each small garden traditionally has at least one cherry laurel tree [Beyhan 2010]. The fruits of the specie have been selling in market with a high price as fresh or dried. Cherry laurel fruits and seeds have been used as traditional medicines for a long time in Turkey because they are high content of potentially health-promoting components [Liyana-Pathirana et al. 2006, Celik et al. 2011, Li et al. 2014]. It is also connected to the heritage of cultural values in the region and makes a cultural bridge between local peoples and their relatives who migrated to the western parts of the country. When the local peoples harvest the cherry laurel fruits they can prepare it as fresh or processes into several special products and send them to relatives living away from region as special gift [Yildiz et al. 2014].

The physical attributes of cherry laurel fruits belong to different accessions are very significant for designing of post-harvesting technologies. Shape is a descriptive attribute of an agricultural product and one of the crucial engineering parameters used in the design of several separating, classifying and grading mechanisms as well. Besides, these descriptive characteristics of the products may also be used for different commercial and industrial purposes [Costa et al. 2011] including genotype/cultivar description that is very important for plant variety rights or cultivar registration [Khanizadeh 1994, Beyer et al. 2002], evaluation of consumer choice [Kays 1999], investigating heritability of product shape attributes [Cannon and Manos 2001] or analyzing shape abnormalities [Brewer et al. 2007].

Presently, machine vision or remote sensing systems have been using instead of manual control of product in several process such as defect detection, grading, sorting and counting in the post-harvest industries [Ruiz-Altisent et al. 2010]. Besides, the shape of a product may also represent a valid tool for foodstuffs origin certification, as required to protect the interest of producers and to identify deceptive products [Costa et al. 2010]. In addition, it was stated that the shape differences among the genotypes/cultivars were an identifier factor to determine similarity/dissimilarity existing between fruit morphology and inheritance [Cannon and Manos 2001].

There are several researches on comparison of size and shape attributes of the different fruits such as almond [Antonucci et al. 2012], apricot [Ahmadi et al. 2008], hazelnut [Menesatti et al. 2008], loquat [Boydas et al. 2012], orange [Costa et al. 2009, Sayinci et al. 2012], pistachio [Ghazanfari et al. 1997], strawberry [Liming and Yanchao 2010] and walnut [Ercisli et al. 2012]. Among the recent studies, Pallottino et al. [2013] compared two refrigeration systems on evaluation of sweet cherry freshness based on their stem thickness and color. Those horticultural crops were defined based upon the measurable parameters such as length, width, thickness, projected area, geometric mean diameter for size attributes, and the computable parameters such as sphericity, shape index, elongation for shape attributes.

Shape of a fruit is a subjective evaluation that varies from person to person on condition that a typical method is not used at the point of the semantic decision to the shape of the product. According to Mohsenin [1986], this is actually a psychophysical subjective assessment. The most common method used to determine similarities or dissimilarities between the fruits of species or genotypes is elliptic Fourier analysis (EFA). This method has been successfully used in many researches concerned with the different fruit species and genotypes such as hazelnut [Menesatti et al. 2008], orange [Costa et al. 2009], apple [Currie et al. 2000] and almond [Antonucci et al. 2012].

This study aimed to determine and compare the shape attributes of twenty-one *P. laurocerasus* accessions naturally growing in the Eastern Black Sea Region in Turkey. The shape attributes in fruits of cheery laurel accessions were defined both descriptively and compared based on elliptic Fourier analysis method.

MATERIAL AND METHODS

Fruit samples. In the study, twenty-one accessions of *Prunus laurocerasus* were used. The accession numbers are shown in Figure 1. The mature fruits were harvested from the districts of Çayeli, Pazar, and Hemsin belongs to Rize province located in the Eastern Black Sea Region of Turkey. The fruits randomly harvested from the trees during the 2013 harvest season in June and July and were labelled with regard to the accessions numbers and preserved in refrigerator boxes and promptly transferred to Erzurum province within the same day in order to analyze. The samples were kept in a refrigerator at temperature of -4°C until the next process. Because all tests were built on determination of gravimetric attributes and taking the accession images, all durations concerned with the analysis were completed within just one day at the Biological Material Laboratory.

For each accessions, a total 32 fruit samples in the bag were randomly selected and the mass of each fruit was measured using an electronic balance (Schimadzu TW423 L, Japan) with sensitivity of 0.001 g. After that, the samples were placed on a white transparent fiberglass surface with dimensions of 7 × 10 cm in the matrix form 2 × 4 in order to prepare digitizing the samples. So, four images comprising from the 32 samples totally were taken for each of accessions. In order to stand firm the samples on the fiberglass surface during carrying to the acquatizion system, a small part of putty was used on the surface.

Digitizing fruit images. The samples were digitized with an image acquatizion system used by Kara et al. [2013]. This system equipped with the illumination implements provided taking the shadowless sample images on the background surface of which is fiberglass, enabled to distinguish the contour of the samples from the background during analysis, and made possible for a precise analysis. The images were obtained from the longitudinal and section orientations of the samples.

A digital camera (Nikon D300, Japan) was used to take the digital images with *.tiff extension file. The distance between the sample and the camera lens was approximately set at 45 cm. In each image, the area of 24 × 36 cm was captured. The resolution for each image was 4288 × 2848 pixels. After the captured images, the images with *.tiff extension file were converted to *.bmp extension file for the next analysis. To calibrate length in millimeters (mm), a ruler with intervals of 1.0 mm was placed beside the fiberglass surface. On the captured images, the length of 1.0 mm was determined to be equal to the 40 pixels.

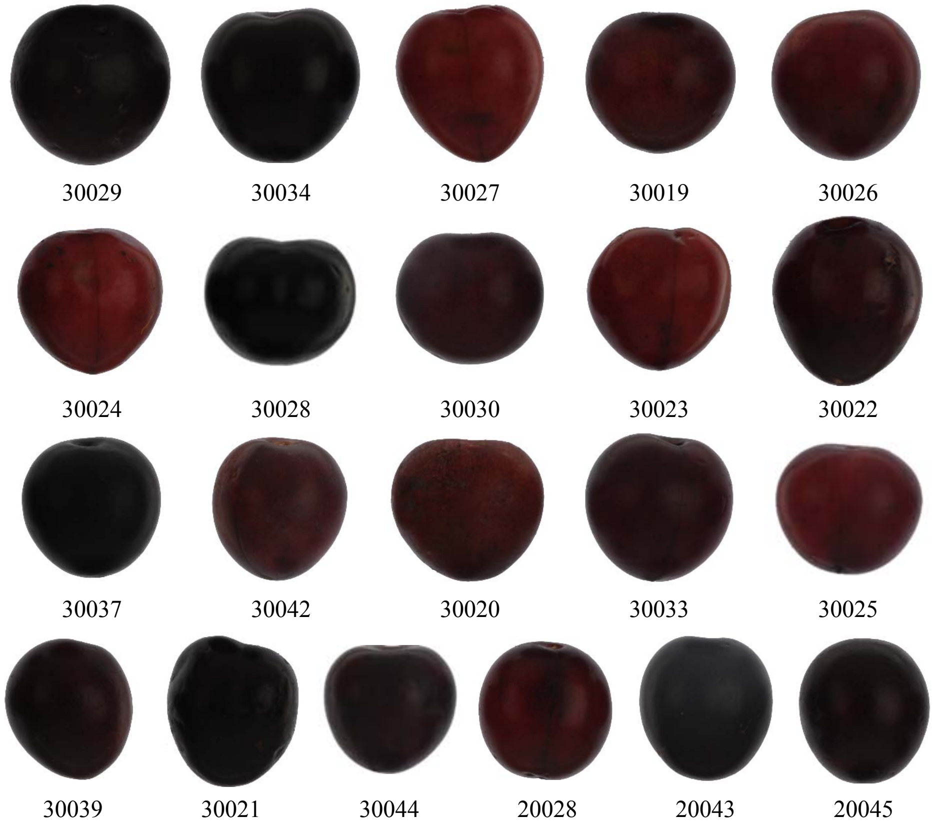

Fig. 1. *Prunus laurocerasus* accessions

Obtaining descriptive data for the genotypes. SigmaScan®Pro 5.0 software was used to determine the size and shape attributes of the fruit samples, and these attributes were defined as descriptive data. The parameters measured by the image processing were projected area (*PA*, mm^2), perimeter (*P*, mm), length (*L*, mm), width (*W*, mm), thickness (*T*, mm), and shape factor (*SF*). The other size parameters concerned with the descriptive data calculated using the following equations:

The volume (*V*, cm^3) of the fruit, shape of which is assumed as sphere, was calculated using the equation (1).

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

The equation (2), (3) and (4) were used in an attempt to calculate the geometric mean diameter (D_g, mm), sphericity (φ, %) and roundness (R) [Mohsenin 1986], respectively (PA_L: major projected area based on length).

$$D_g = (L \cdot W \cdot T)^{1/3} \tag{2}$$

$$\varphi = \frac{D_g}{L} \cdot 100 \tag{3}$$

$$R = \frac{PA}{PA_L} \tag{4}$$

The surface area (S, cm^2) data was obtained from the equation (5) given by McCabe et al. [1986] and cited by Olajide and Ade-Omowaye [1999].

$$S = \pi \cdot D_g^2 \tag{5}$$

The elongation which is the ratio of major distance to minor distance was calculated for two orientations using the equation (6) and (7).

$$E = \frac{L}{W} \quad \text{for the longitudinal orientation} \tag{6}$$

$$E = \frac{W}{T} \quad \text{for the section orientation} \tag{7}$$

The shape index (SI) defining the shape of a product [Ercisli et al. 2012] was calculated using the equation (8).

$$SI = 2 \cdot \frac{L}{W + T} \tag{8}$$

The equation (9) calculated automatically by the image processing software determined the shape factor (SF) of the fruit.

$$SF = 4 \cdot \pi \cdot \frac{PA}{P^2} \tag{9}$$

Elliptic Fourier analysis. Elliptic Fourier analysis (EFA) described by Kuhl and Giardina [1982] at first, implement a forward transform which creates a closed shape spectrum of a product based on the x- and y-outline. In the EFA, a specified number of harmonics were obtained from the shape spectrum and reconstructed the x- and y-outline. As a consequence, the shape descriptors create defining the contour of the product. By default, the first 20 harmonics of the elliptic Fourier descriptor (EFD's) coefficients in the principal component (PC) analysis were used to describe the shape variation among the *Prunus laurocerasus* accessions.

SHAPE software version 1.3 [Iwata et al. 2012] was used to obtain the principal component (PC) scores, and to create EFD's which define the contour of the *P. laurocerasus* fruit. This software performs image processing, contour recording, derivation of EFD's, PC analysis of EFD's and visualization of shape variations estimated by the PC's. The flow diagram showing the test stages was given in Figure 2.

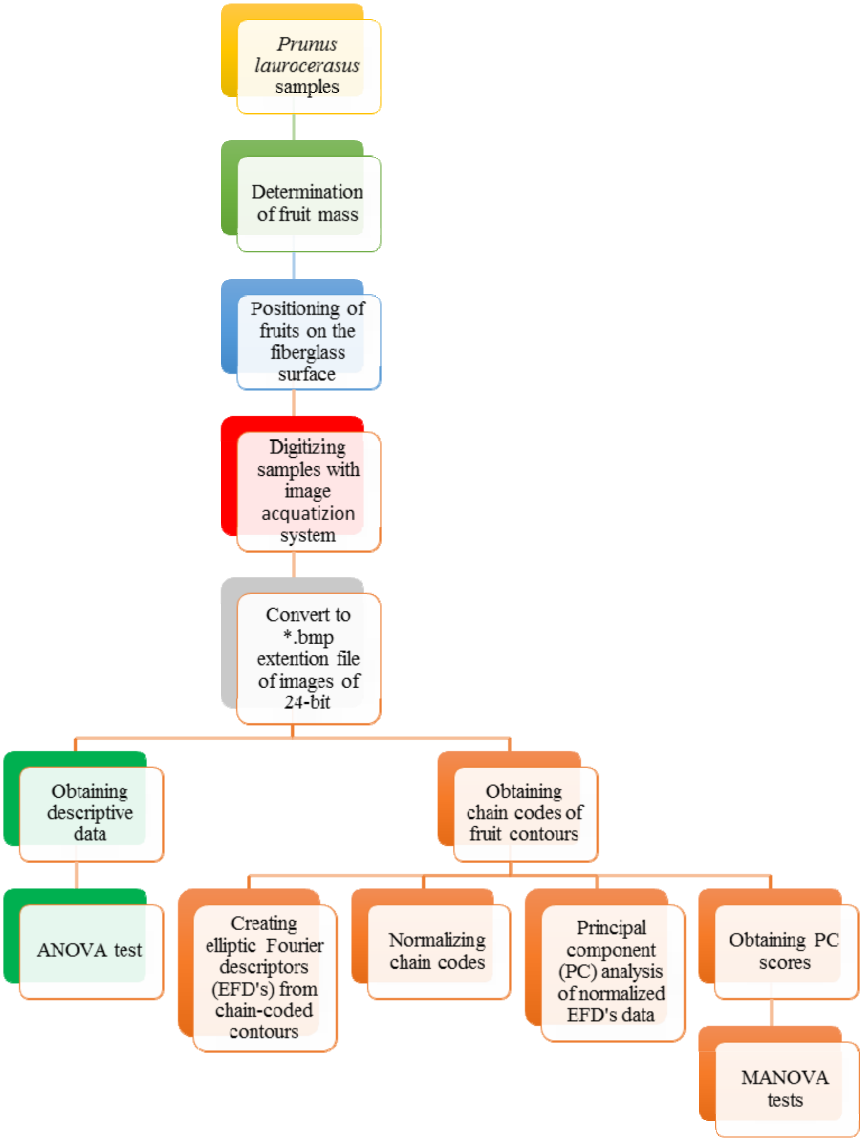

Fig. 2. The diagram of the analysis stages of the samples

Statistical analysis. Analysis of variance (ANOVA) was performed to the descriptive data of twenty-one *Prunus laurocerasus* genotypes. SPSS statistical software version 20.0 [IBM 2010] was used in order to test the descriptive data. The difference between the mean values was indicated with the LSD (Least significant difference) value. The statistical values concerned with the descriptive data and the results of the ANOVA test were compendiously presented.

The principal component scores obtained from the normalized chain codes were assessed for multivariate tests (MANOVA) using PAST statistical software version 3.01 [Hammer et al. 2001]. The similarities or dissimilarities among the accessions was tested using Hotelling's pairwise comparisons with Bonferroni correction and squared Mahalanobis distances which make possible pairwise comparisons of the accessions. In order to determine the class/classes of a typical accession within different accessions, linear discriminant analysis (LDA) was performed to the PC score data using SPSS statistical software version 20.0 [IBM 2010]. The LDA analysis corresponds to the jackknifed option in PAST statistical software version 3.01. A hierarchical cluster analysis performed by using similarity index of Chord in the unweighted pair group method with arithmetic mean assigned the location of the accessions.

RESULTS

Size, shape and gravimetric attributes of *P. laurocerasus* genotypes. The results of the ANOVA test showed that the *Prunus laurocerasus* accessions were substantially differed each other in terms of the gravimetric, size and shape attributes. The differences between the means defining descriptive attributes of the *P. laurocerasus* accessions might be compared in reference to the values of least significant differences (LSD). The means given in Table 1 showed that the 30023, 30024 and 30027 accessions of *P. laurocerasus* had the highest means while the means of the 20043, 30028 and 30030 accessions were found the lowest as to the gravimetric and size attributes. The accessions of the *P. laurocerasus* 30019, 30028, 30030 and 30033 were found to be the closest each other with sphericity ranging from 96.2% to 97.8% (tab. 2). The 20045, 30021, 30042 and 30044 genotypes had the lowest sphericity, roundness and shape factor means among the genotypes.

Shape analysis based on elliptic Fourier descriptors. The shape data including PCA based on elliptic Fourier descriptors (EFD's) revealed the differences between the accessions by using Hotelling's pairwise comparisons, linear discriminant function analysis and cluster analysis. The shape variations between the contours of the accessions and their seven significant principal components (PCs) were shown in Figure 3. PC1 to PC7 constituted 36.5, 30.4, 17.6, 4.0, 3.8, 1.6 and 1.4%, of the variation for a total of 95.3%.

The results of the MANOVA test are given in Table 3. The result showed that the independent variables comprising the first seven principal components (PC1 to PC7) obtained from the EFD's were statistically significant ($P < 0.01$) as indicated by Wilks' Lambda and Pillai Trace statistics. The Hotelling's pairwise comparison results showed that the 20045, 30021 and 30028 accessions had the most distinctive characteristics as

Table 1. Gravimetric and size features of *P. laurocerasus* accessions (mean ±standard deviation)

Accessions	Gravimetric features		Size features					
	mass (g)	volume (cm^3)	projected area (mm^2)	surface area (cm^2)	length (mm)	width (mm)	thickness (mm)	geometric mean diameter (mm)
20028	3.43 ±0.38	3.17 ±0.47	277.6 ±18.4	10.3 ±1.3	19.2 ±0.6	18.8 ±0.7	16.5 ±2.5	18.1 ±1.2
20043	3.06 ±0.49	2.88 ±0.45	255.3 ±28.6	9.7 ±1.0	18.7 ±1.0	17.7 ±1.1	16.4 ±0.9	17.6 ±1.0
20045	3.15 ±0.30	2.98 ±0.29	265.0 ±17.1	9.9 ±0.7	19.4 ±0.6	17.7 ±0.6	16.3 ±1.3	17.8 ±0.6
30019	4.86 ±0.44	4.73 ±0.57	352.1 ±23.9	13.6 ±1.2	21.6 ±0.7	21.6 ±0.8	19.2 ±1.5	20.8 ±0.9
30020	4.89 ±0.74	4.79 ±0.82	359.3 ±38.0	13.6 ±1.6	22.2 ±1.1	21.0 ±1.4	19.3 ±1.3	20.8 ±1.2
30021	4.35 ±0.67	4.47 ±0.82	355.6 ±39.8	13.1 ±1.4	22.5 ±1.3	20.8 ±1.3	18.2 ±1.5	20.4 ±1.1
30022	5.31 ±0.96	5.33 ±0.98	376.3 ±49.6	14.7 ±1.8	22.6 ±1.6	21.7 ±1.4	20.4 ±1.3	21.6 ±1.4
30023	6.17 ±1.20	6.22 ±1.06	425.2 ±56.0	16.2 ±1.9	24.2 ±1.4	23.2 ±1.8	20.8 ±1.4	22.7 ±1.4
30024	6.01 ±0.62	5.98 ±0.64	418.7 ±31.2	15.8 ±1.2	23.7 ±0.9	23.3 ±1.0	20.4 ±1.4	22.4 ±0.9
30025	3.28 ±0.35	3.24 ±0.35	273.9 ±20.5	10.5 ±0.8	19.3 ±0.7	19.0 ±0.7	16.7 ±0.8	18.3 ±0.7
30026	4.64 ±0.90	4.52 ±0.95	344.5 ±47.6	13.1 ±1.9	21.7 ±1.5	20.7 ±1.6	18.9 ±1.9	20.4 ±1.5
30027	6.22 ±0.82	6.28 ±0.82	423.4 ±38.8	16.4 ±1.5	24.0 ±1.1	23.3 ±1.3	21.3 ±1.2	22.8 ±1.0
30028	3.01 ±0.65	3.11 ±0.74	244.6 ±39.0	10.2 ±1.7	18.3 ±1.5	18.3 ±1.6	17.3 ±1.5	18.0 ±1.5
30029	4.10 ±0.74	3.88 ±0.82	314.2 ±38.9	11.9 ±1.6	20.5 ±1.3	20.4 ±1.4	17.7 ±2.2	19.4 ±1.4
30030	2.74 ±0.32	2.75 ±0.34	239.9 ±20.5	9.5 ±0.8	17.9 ±0.8	17.7 ±0.8	16.4 ±0.8	17.3 ±0.7
30033	4.32 ±0.47	4.08 ±0.64	313.3 ±23.8	12.3 ±1.4	20.4 ±0.8	20.3 ±0.8	18.6 ±2.2	19.7 ±1.2
30034	3.20 ±0.21	3.06 ±0.32	268.7 ±11.7	10.1 ±0.8	19.0 ±0.5	18.8 ±0.4	16.2 ±1.7	17.9 ±0.8
30037	5.52 ±0.51	5.26 ±0.64	380.7 ±24.8	14.5 ±1.2	22.5 ±0.8	22.0 ±0.8	20.1 ±1.5	21.5 ±0.9
30039	3.84 ±0.45	3.71 ±0.45	299.3 ±22.9	11.5 ±0.9	20.4 ±0.7	19.2 ±0.9	18.0 ±1.1	19.2 ±0.8
30042	3.97 ±0.63	3.71 ±0.64	312.4 ±31.7	11.4 ±1.4	20.8 ±1.1	19.4 ±1.1	17.2 ±2.3	19.1 ±1.2
30044	3.33 ±0.64	3.18 ±0.62	278.1 ±34.2	10.3 ±1.4	19.5 ±1.1	18.6 ±1.3	16.3 ±1.8	18.1 ±1.3
P (Sig. level)	**	**	**	**	**	**	**	**
LSD value	0.52	0.54	27.10	1.10	0.90	0.90	1.30	0.90
Mean ±SD	4.22 ±1.24	4.13 ±1.29	321.1 ±66.2	12.3 ±2.6	20.8 ±2.1	20.1 ±2.1	18.1 ±2.3	19.7 ±2.0
Range	1.71–7.66	1.76–7.64	160.3–494.5	6.2–18.7	15.2–26.1	6.2–25.1	8.0–23.1	14.1–24.4

** – very significant ($P < 0.01$)

Table 2. Shape features of *Prunus laurocerasus* accessions (mean ±standard deviation)

Accessions	Shape features							
	sphericity (%)	shape index	longitudinal orientation			cross orientation		
			roundness	elongation	shape factor	roundness	elongation	shape factor
20028	93.9 ±5.7	1.10 ±0.10	0.95 ±0.02	1.02 ±0.02	0.876 ±0.007	0.93 ±0.03	1.18 ±0.31	0.873 ±0.008
20043	94.1 ±2.0	1.10 ±0.04	0.93 ±0.03	1.06 ±0.04	0.881 ±0.009	0.93 ±0.02	1.08 ±0.03	0.878 ±0.006
20045	91.5 ±3.0	1.14 ±0.06	0.89 ±0.02	1.10 ±0.02	0.879 ±0.006	0.93 ±0.02	1.09 ±0.13	0.878 ±0.006
30019	96.2 ±2.4	1.06 ±0.04	0.96 ±0.01	1.00 ±0.01	0.871 ±0.007	0.93 ±0.01	1.13 ±0.09	0.866 ±0.007
30020	93.6 ±1.4	1.10 ±0.03	0.93 ±0.02	1.06 ±0.03	0.870 ±0.005	0.93 ±0.02	1.09 ±0.04	0.872 ±0.007
30021	90.7 ±3.5	1.16 ±0.07	0.89 ±0.03	1.08 ±0.05	0.859 ±0.008	0.88 ±0.04	1.16 ±0.12	0.854 ±0.015
30022	95.3 ±1.8	1.07 ±0.03	0.93 ±0.04	1.04 ±0.03	0.870 ±0.007	0.94 ±0.01	1.07 ±0.02	0.872 ±0.007
30023	93.7 ±2.3	1.10 ±0.04	0.92 ±0.03	1.05 ±0.04	0.864 ±0.010	0.92 ±0.02	1.11 ±0.08	0.864 ±0.006
30024	94.5 ±2.4	1.09 ±0.04	0.95 ±0.02	1.02 ±0.02	0.865 ±0.009	0.92 ±0.02	1.15 ±0.10	0.868 ±0.007
30025	94.9 ±1.1	1.08 ±0.02	0.94 ±0.02	1.02 ±0.01	0.874 ±0.008	0.90 ±0.02	1.14 ±0.05	0.869 ±0.009
30026	93.8 ±3.1	1.10 ±0.05	0.93 ±0.04	1.05 ±0.04	0.872 ±0.008	0.94 ±0.02	1.10 ±0.11	0.872 ±0.008
30027	95.2 ±2.4	1.08 ±0.04	0.94 ±0.03	1.03 ±0.03	0.869 ±0.009	0.93 ±0.02	1.10 ±0.06	0.873 ±0.006
30028	97.8 ±1.5	1.03 ±0.03	0.92 ±0.02	1.00 ±0.02	0.866 ±0.008	0.93 ±0.02	1.06 ±0.03	0.868 ±0.006
30029	94.8 ±4.1	1.08 ±0.07	0.94 ±0.02	1.01 ±0.01	0.874 ±0.007	0.92 ±0.02	1.17 ±0.19	0.876 ±0.006
30030	97.0 ±1.2	1.05 ±0.02	0.96 ±0.02	1.01 ±0.01	0.880 ±0.006	0.93 ±0.02	1.08 ±0.03	0.877 ±0.006
30033	96.4 ±3.7	1.06 ±0.06	0.96 ±0.01	1.01 ±0.01	0.875 ±0.007	0.95 ±0.01	1.11 ±0.17	0.880 ±0.005
30034	94.1 ±3.8	1.09 ±0.06	0.94 ±0.02	1.02 ±0.02	0.874 ±0.006	0.90 ±0.03	1.18 ±0.18	0.873 ±0.007
30037	95.4 ±2.5	1.07 ±0.04	0.95 ±0.02	1.02 ±0.02	0.882 ±0.004	0.94 ±0.02	1.11 ±0.10	0.878 ±0.005
30039	93.7 ±2.5	1.10 ±0.04	0.91 ±0.04	1.07 ±0.04	0.873 ±0.006	0.95 ±0.02	1.07 ±0.07	0.876 ±0.007
30042	91.7 ±4.2	1.14 ±0.07	0.92 ±0.03	1.07 ±0.03	0.875 ±0.005	0.94 ±0.02	1.15 ±0.21	0.877 ±0.006
30044	92.6 ±3.3	1.12 ±0.06	0.92 ±0.03	1.05 ±0.03	0.873 ±0.010	0.91 ±0.02	1.15 ±0.15	0.872 ±0.007
P (Sig. level)	**	**	**	**	**	**	**	**
LSD value	2.50	0.04	0.02	0.02	0.006	0.02	0.11	0.006
Mean ±SD	94.3 ±3.4	1.09 ±0.06	0.93 ±0.03	1.04 ±0.04	0.872 ±0.009	0.93 ±0.03	1.12 ±0.13	0.872 ±0.009
Range	74.7–99.6	1.00–1.42	0.81–0.99	0.97–1.18	0.834–0.893	0.82–0.98	1.00–2.33	0.800–0.890

** – significant ($P < 0.01$)

Table 3. Similarities and differences among the accessions based on *Prunus laurocerasus* outlines

A. MANOVA results (computed in PAST ver. 3.01)

Effects	Statistics	Value	Hypothesis *df*	Error *df*	*F*	*P* (Sigma)
Accessions	Wilks' Lambda	0.3100	140	3246	4.471	137.00E-55
	Pillai Trace	0.9942	140	3451	4.080	3.60E-48

B. The results of the Hotelling's pairwise comparisons. Bonferroni corrected *P* values in lower triangle, Mahalanobis distances in upper triangle (computed in PAST ver. 3.01)

Gen.	30029	30034	30027	30019	30026	30024	30028	30030	30023	30022	30037	30042	30020	30033	30025	30039	30021	30044	20028	20043	20045
30029		1.54	2.10	1.04	*3.05*	1.96	1.74	0.43	*4.30*	*3.01*	2.00	*4.00*	*3.03*	0.76	0.54	*4.40*	*7.22*	*3.86*	1.98	2.24	*7.02*
30034	1.4E+00		1.26	0.63	1.86	0.75	*3.71*	0.59	2.23	2.24	1.12	*3.39*	2.25	0.52	2.69	*3.59*	*6.54*	2.47	0.88	1.96	*6.69*
30027	6.4E-01	1.1E+01		1.23	1.30	1.05	*5.33*	1.17	1.06	0.43	0.94	1.80	0.66	1.46	*3.85*	2.36	*4.67*	1.59	0.64	1.07	*6.38*
30019	2.3E+01	8.1E+01	2.2E+01		2.07	0.29	*3.81*	0.40	3.32	2.43	0.36	3.47	1.65	0.85	1.93	*4.11*	*7.27*	3.51	0.49	1.65	*7.29*
30026	*3.2E-02*	1.4E+00	1.9E+01	2.3E+00		1.75	*3.86*	2.11	1.12	1.26	1.52	0.72	1.56	2.80	3.48	0.51	1.77	1.73	1.68	1.20	2.38
30024	1.0E+00	5.6E+01	3.6E+01	1.8E+02	5.4E+00		*4.73*	0.87	2.96	2.45	0.21	3.02	1.21	1.63	2.99	*3.78*	*6.55*	3.47	0.23	1.44	*6.76*
30028	2.1E+00	*4.6E-03*	*1.1E-03*	*2.8E-02*	*2.5E-02*	*3.6E-03*		2.51	*6.41*	*5.89*	*5.14*	*4.35*	*5.67*	3.47	0.75	*4.15*	*5.95*	*6.32*	*5.10*	3.48	*4.11*
30030	1.3E+02	9.0E+01	2.7E+01	1.6E+02	2.0E+00	5.8E+01	6.9E-01		3.13	2.17	1.12	2.92	1.77	0.42	1.22	*3.62*	*6.61*	2.92	0.75	1.43	*6.77*
30023	*9.3E-04*	4.2E-01	3.5E+01	8.9E-02	3.1E+01	2.2E-01	*1.4E-04*	1.4E-01		0.53	2.78	1.77	2.06	2.90	*6.11*	1.33	2.92	1.37	2.64	2.01	*4.75*
30022	*3.6E-02*	4.1E-01	1.5E+02	8.6E-01	2.1E+01	8.1E-01	*3.5E-04*	1.7E+00	1.3E+02		2.06	1.49	1.19	2.16	*4.79*	1.64	*3.68*	1.37	1.85	1.44	*5.80*
30037	3.1E+00	3.3E+01	7.3E+01	1.8E+02	2.1E+01	2.0E+02	*1.6E-02*	5.0E+01	1.4E+00	6.4E+00		3.01	1.35	1.73	3.04	3.55	*6.10*	2.92	0.35	1.76	*6.69*
30042	*2.1E-03*	*1.2E-02*	4.7E+00	6.3E-02	8.3E+01	1.9E-01	*8.2E-03*	2.4E-01	5.2E+00	1.1E+01	8.6E-01		1.22	*4.20*	*4.38*	0.42	1.58	2.87	2.53	0.86	2.57
30020	*3.4E-02*	3.9E-01	9.6E+01	7.0E+00	9.1E+00	2.4E+01	*5.4E-04*	5.1E+00	2.3E+00	2.5E+01	3.0E+01	2.3E+01		2.91	*4.36*	2.36	*4.82*	*3.59*	0.91	0.40	*6.00*
30033	5.4E+01	1.1E+02	1.2E+01	6.1E+01	3.3E-01	7.6E+00	6.3E-02	1.5E+02	2.6E-01	1.7E+00	1.3E+01	*1.2E-02*	2.5E-01		2.06	*4.45*	*7.74*	2.49	1.45	2.58	*8.27*
30025	1.0E+02	9.7E-02	*2.5E-02*	3.3E+00	6.1E-02	2.0E-01	7.8E+01	2.3E+01	*2.4E-04*	*3.2E-03*	8.0E-01	*7.6E-03*	*8.1E-03*	2.3E+00		*4.67*	*7.11*	*5.31*	3.19	3.03	*5.93*
30039	*7.2E-04*	*6.6E-03*	1.0E+00	*1.4E-02*	1.3E+02	*3.0E-02*	*1.3E-02*	*4.4E-02*	1.7E+01	7.2E+00	2.8E-01	1.5E+02	1.0E+00	*6.7E-03*	*4.1E-03*		0.67	2.51	3.53	1.60	1.44
30021	*1.0E-06*	*4.4E-06*	*4.1E-03*	*3.0E-05*	5.1E+00	*1.0E-04*	*3.2E-04*	*9.3E-05*	2.4E-01	*3.8E-02*	*3.3E-03*	8.7E+00	*3.0E-03*	*1.4E-05*	*3.9E-05*	9.3E+01		*3.82*	*6.28*	*3.83*	0.95
30044	*3.1E-03*	1.9E-01	8.5E+00	5.6E-02	5.6E+00	6.3E-02	*1.6E-04*	2.4E-01	1.5E+01	1.5E+01	1.0E+00	2.8E-01	*4.6E-02*	7.3E-01	*1.1E-03*	6.9E-01	*2.7E-02*		2.58	*3.84*	*6.24*
20028	9.5E-01	3.8E+01	9.9E+01	1.4E+02	6.5E+00	2.0E+02	*1.7E-03*	7.8E+01	5.0E-01	4.1E+00	1.8E+02	6.6E-01	5.3E+01	1.2E+01	1.2E-01	5.4E-02	*1.7E-04*	5.8E-01		1.42	*7.22*
20043	4.0E-01	1.0E+00	3.5E+01	7.0E+00	2.4E+01	1.3E+01	6.0E-02	1.3E+01	2.7E+00	1.3E+01	1.2E+01	6.0E+01	1.6E+02	5.8E-01	1.8E-01	8.3E+00	*2.7E-02*	*2.6E-02*	1.3E+01		*4.12*
20045	*1.6E-06*	*3.2E-06*	*1.4E-04*	*2.9E-05*	9.7E-01	*7.2E-05*	*1.4E-02*	*7.0E-05*	*3.5E-03*	*4.2E-04*	*1.4E-03*	6.0E-01	*2.8E-04*	*5.8E-06*	*3.3E-04*	1.3E+01	4.8E+01	*1.8E-04*	*3.3E-05*	*1.4E-02*	

Table 4. Summary of canonical discriminant functions and classification results (%) from linear discrimination analysis of the data obtained from Elliptical Fourier Analysis (14.8% of original grouped cases correctly classified)

	Eigenvalues statistic				Wilks' Lambda statistic				
Function	eigenvalue	% of variance	cumulative	canonical correlation	test of functions	Wilks' Lambda	Chi-square	df	Sig.
1	0.558	59.4	59.4	0.599	1 – 3	0.456	393.009	60	0.000
2	0.297	31.6	91.0	0.478	2 – 3	0.711	170.792	38	0.000
3	0.084	9.0	100.0	0.279	3	0.922	40.576	18	0.002

Accessions	Linear discriminant analysis for *Prunus laurocerasus* assignment																				
	30029	30034	30027	30019	30026	30024	30028	30030	30023	30022	30037	30042	30020	30033	30025	30039	30021	30044	20028	20043	20045	Total
30029	*28.1*	21.9	–	–	–	9.4	28.1	–	–	–	–	–	6.3	–	–	–	–	3.1	–	–	3.1	100
30034	18.8	*28.1*	–	–	–	6.3	9.4	–	3.1	–	–	–	15.6	–	–	–	–	12.5	6.3	–	–	100
30027	4.2	29.2	*–*	–	–	4.2	4.2	–	–	–	–	8.3	20.8	4.2	–	–	12.5	4.2	–	8.3	–	100
30019	33.3	29.2	–	*8.3*	–	20.8	–	–	4.2	–	–	–	–	–	–	–	–	–	4.2	–	–	100
30026	–	20.8	–	–	*–*	4.2	–	–	4.2	8.3	–	8.3	4.2	–	–	4.2	16.7	12.5	4.2	4.2	8.3	100
30024	8.3	25.0	–	–	–	*16.7*	4.2	–	–	–	–	–	33.3	4.2	4.2	–	4.2	–	–	–	–	100
30028	12.5	20.8	–	–	–	–	*50.0*	–	–	–	–	–	4.2	–	–	–	–	–	–	8.3	4.2	100
30030	33.3	25.0	–	–	–	12.5	8.3	*–*	–	–	–	–	–	–	–	–	–	4.2	4.2	12.5	–	100
30023	4.2	20.8	–	–	–	–	–	–	*8.3*	–	–	8.3	20.8	–	4.2	4.2	16.7	8.3	–	4.2	–	100
30022	8.3	16.7	–	–	–	–	4.2	–	4.2	*–*	–	4.2	20.8	–	–	–	16.7	12.5	–	4.2	8.3	100
30037	16.7	33.3	–	–	–	16.7	–	–	–	–	*–*	–	33.3	–	–	–	–	–	–	–	–	100
30042	4.2	–	4.2	–	–	4.2	–	–	4.2	–	–	*8.3*	8.3	–	–	–	37.5	8.3	4.2	–	16.7	100
30020	–	8.3	–	–	–	4.2	–	–	–	–	–	16.7	*29.2*	4.2	–	–	12.5	4.2	4.2	16.7	–	100
30033	20.8	37.5	–	–	–	4.2	16.7	–	–	–	–	–	12.5	*4.2*	4.2	–	–	–	–	–	–	100
30025	29.2	4.2	–	4.2	–	–	33.3	–	–	–	–	4.2	4.2	–	*–*	–	–	12.5	4.2	–	4.2	100
30039	4.2	8.3	–	–	4.2	–	–	–	4.2	–	–	4.2	12.5	–	–	*–*	20.8	8.3	4.2	8.3	20.8	100
30021	4.2	–	–	–	–	4.2	–	–	–	4.2	–	4.2	12.5	–	–	8.3	*37.5*	4.2	–	4.2	16.7	100
30044	4.2	29.2	–	–	–	–	–	–	8.3	–	–	4.2	8.3	4.2	–	4.2	20.8	*12.5*	–	4.2	–	100
20028	8.3	20.8	–	4.2	–	4.2	–	–	4.2	–	–	–	25.0	–	–	4.2	–	12.5	*16.7*	–	–	100
20043	12.5	8.3	4.2	–	–	4.2	–	–	4.2	–	–	–	25.0	–	–	4.2	8.3	–	4.2	*4.2*	20.8	100
20045	4.2	4.2	–	–	–	–	–	–	–	–	–	8.3	–	–	–	16.7	20.8	–	–	–	*45.8*	100

compared to the other accessions. In general, the accessions which Mahalanobis distance is smaller than 3 showed statistically similar shape attributes (*P* > 0.05). It might be concluded that the 20043, 20028, 30026, 30033 and 30037 accessions with the lowest Mahalanobis distances have the similar shape characteristics in common when compared the other *P. laurocerasus* accessions.

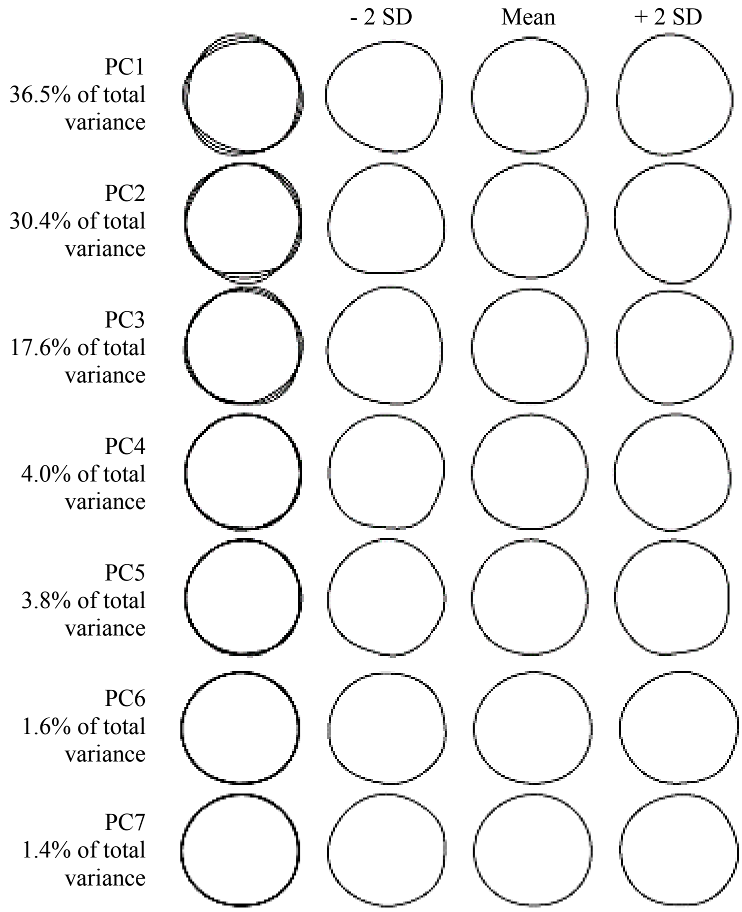

Fig. 3. Principal components of *P. laurocerasus* accessions. The first seven variables comprise of 95.3% of the total variance. The contours from left to right display the PC scores corresponding to: (mean - 2 SD), mean, (mean + 2 SD)

The results of the analysis test concerned with the canonical discriminant functions were shown in Table 4. The higher classification rates revealed a distinctive attribute among the accessions. The 20045, 30021 and 30028 were the accessions that had the highest classification rates within own group with the proportion of 45.8, 37.5 and

50.0%, respectively, among the *P. laurocerasus* accessions. The proportion of 14.8% in the correctly classification showed that the several accessions had the common attributes in terms of the shape characteristics.

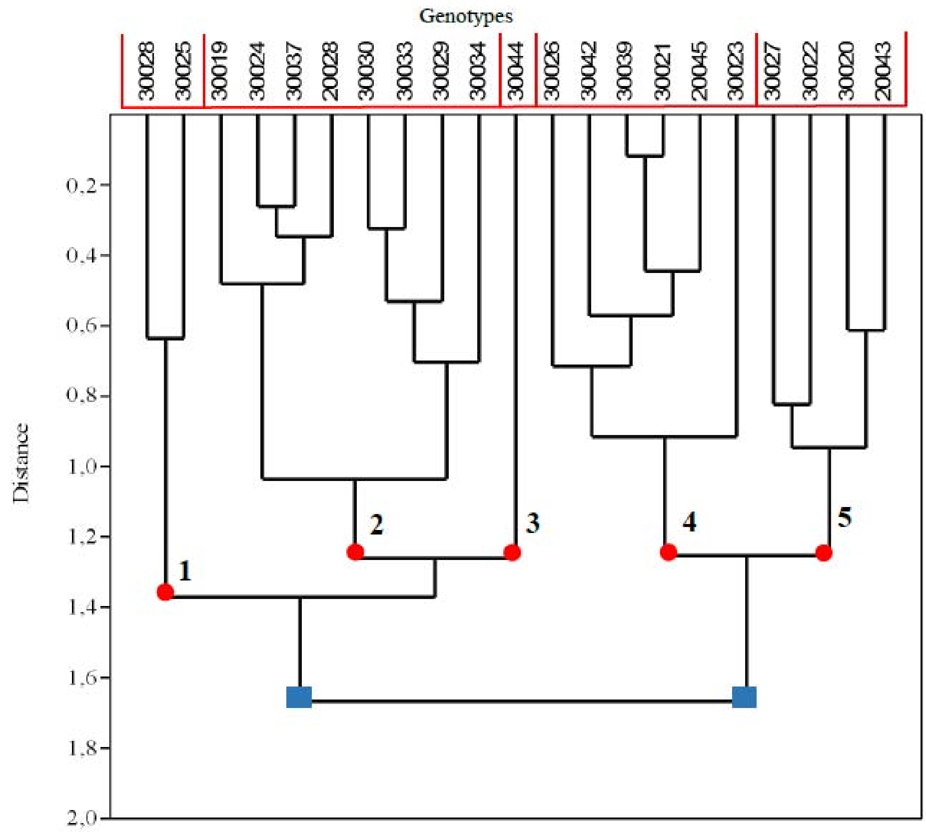

Fig. 4. Dendrogram of *P. laurocerasus* accessions based on the first seven PCs' scores using hierarchical cluster method (used similarity index of Chord in the unweighted pair group method with arithmetic mean (UPGMA) using PAST ver. 3.01, $r = 0.831$)

As seen in Figure 4, the hierarchical cluster analysis divided the *P. laurocerasus* accessions into two main groups (shown with square symbol). The first main group had three subgroups as shown with the circle symbol (cluster 1, 2, and 3). The 1st cluster included the 30025 and 30028 accessions. The accessions 20028, 30019, 30024, 30029, 30030, 30033, 30034 and 30037 placed in the 2nd cluster. Accession 30044 clustered separately in 3rd cluster. The 4th and 5th clusters placed in the second main group. The accessions in the 4th cluster were 20045, 30021, 30023, 30026, 30039 and 30042, respectively. There were four accessions placed in the 5th cluster were 20043, 30020, 30022 and 30027, respectively.

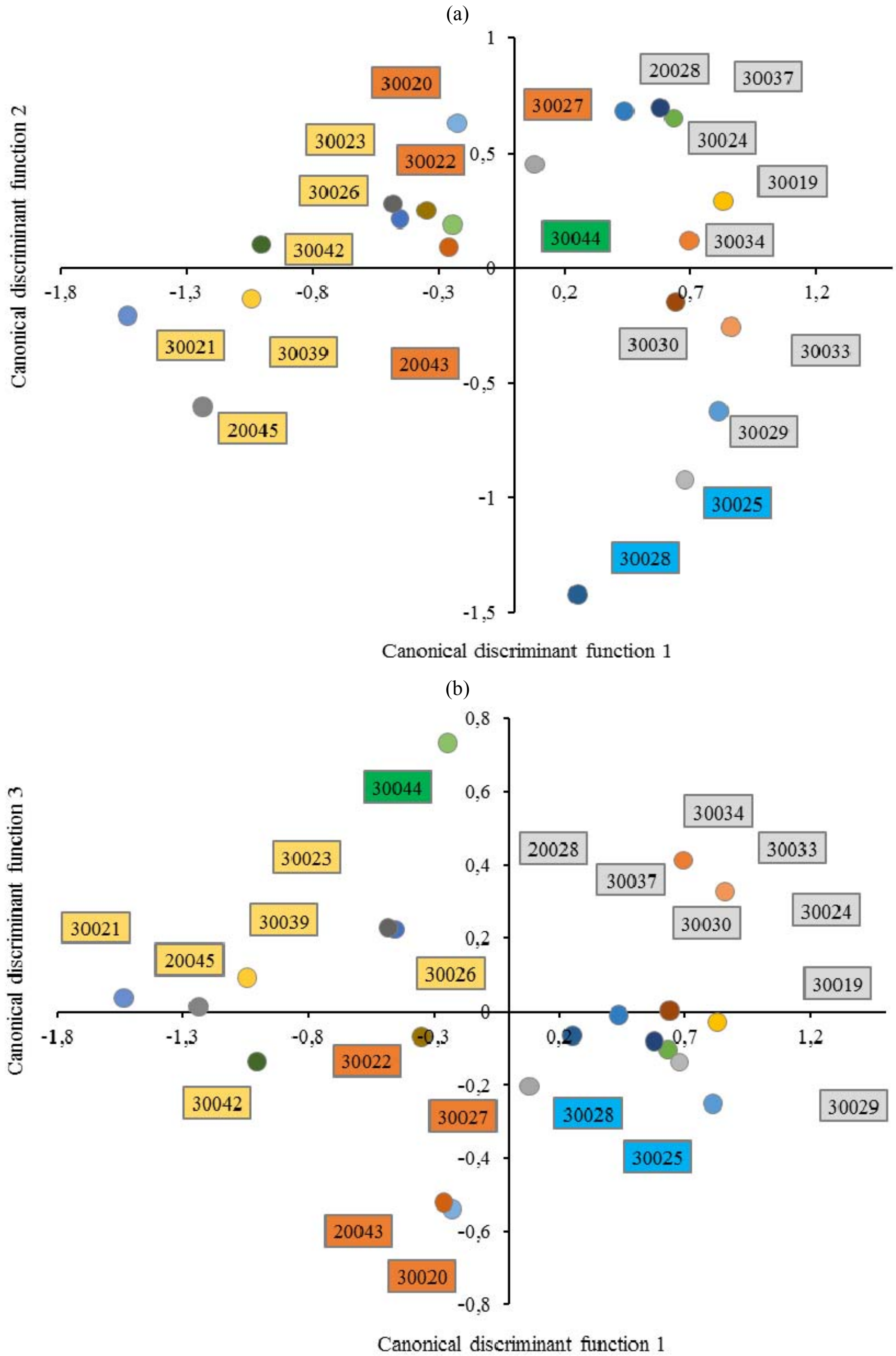

Fig. 5. Group centroids of *P. laurocerasus* accessions at canonical discriminant functions

Figure 5 shows the group centroids of the *P. laurocerasus* accessions based on the scores obtained from the linear discriminant function analysis. The group centroids of the accessions were colored in reference to the results of the cluster analysis. According to the group centroids of the *P. laurocerasus* accessions in Figure 5a, showing the relation between the function 1 and 2, the outmost accessions were 20045, 30021 and 30028. In the Figure 5b concerned with the relation between function 1 and 3, the 30044 accessions staying the outmost of the axis was found compatible with the cluster analysis.

DISCUSSION

Statistically evaluation of data analysis. In general, it might be concluded that the relation between the gravimetric, size and shape attributes defining descriptive data of the *P. laurocerasus* accessions was insignificant. For instance, the means concerned with descriptive shape data of the accessions which had the highest mass was very close to the overall mean in conjunction with the appearances of the accessions indicating very close to sphere. But, the results of the statistical analysis showed existing the distinctive variations between the accessions with regard to their descriptive shape data. The Elliptic Fourier descriptors revealed clearly the similarities or dissimilarities of the accessions.

Wilk's Lambda statistics in Table 3 is the percent of the variance in the dependent variables, which is not clarified by differences in the independent variables. The smaller the Wilk's Lambda statistic means that the differences between the groups being analyzed to increase and ranges from 0 to 1. Pillai Trace statistic, which is considered the most reliable among the Multivariate measures, takes account of the sum of the variance in the dependent variable that is clarified by the greatest discrimination of the independent variables [Foster at al. 2006]. Both statistics demonstrated clearly the differences among the *P. laurocerasus* accessions with regard to the shape discrimination based on the EFD's. In the Hotelling's pairwise comparisons test, the accessions significance level (*P*) which is lower than 0.05 were displayed as italic. These indications showed the differences among the accessions. The accessions Mahalanobis distances of which were lower than 3 indicating the pairwise accessions were statistically insignificant.

The discriminant function analysis was performed using the stepwise method instead of the overall method so that the independent variables were not included into the analysis. As seen in Table 4, three canonical discriminant functions were obtained. The significant dependent variables were determined as PC1, PC2 and PC4 by the statistical test, and the other PC's were not used in the analysis. The canonical correlation value is a proportion of the total variance, and shows the relation between discriminant scores and groups. The square of the canonical correlation value shows a proportion that can be explained of the total variance in the dependent variable. Accordingly, the PC1, PC2 and PC4 explain the proportion of 35.9, 22.8, and 7.8% of total variance among the *P. laurocerasus* accessions that is the dependent variable, respectively. The higher eigenvalue statistics mean that the higher proportion of the total variance in dependent variable can be explained by that function. Because the eigenvalue statistics which are higher than 0.40 provide a best discrimination in dependent variable [Kalayci 2006], it can be concluded that the function 1 provides a best discrimination. Besides, the Wilk's Lambda statistic is defined as a proportion of the total variance in the discriminant scores not explained by differences among the groups, here 45.6% for the test function from 1 to 3, and analyzed the significance of the eigenvalue statistic. The test functions obtained from the statistical analysis were statistically found significant ($P < 0.01$).

The distance between two accessions on the dendrogram (fig. 4) based on the unweighted pair group method (UPGMA) with arithmetic mean was calculated as the mean distance between all pairs of the accessions in two different clusters. As the distance on y-axis of the dendrogram decreased for the accessions, the number of cluster increased, and the shape differences distinguishing the accessions revealed clearly. After forming the clusters, the 30021 and 30039 had the closest accessions among the accessions. Likewise, the 30024 and 30037 accessions were the second rank in terms of the similarity distance.

The centroid locations of the accession groups in Figure 5a and Figure 5b were in excellent compliance with the cluster analysis. The group centroids colored with regard to the cluster analysis presented the important information about the dissimilarity or similarity between the accessions. The accessions grouped in reference to the hierarchical cluster method were obtained from the functions of the linear discriminant analysis, and provided useful information about the similarity of *P. laurocerasus* accessions.

Revealing of differences and similarities among *P. laurocerasus* accessions. In terms of the morphological attributes, most of the *P. laurocerasus* accessions in this study were considerably similar to the cherry laurel genotypes in the studies of Celik et al. [2011] and Kalyoncu et al. [2013] while the size and gravimetric attributes of the cherry laurel fruits in the study of Çalışır and Aydın [2004] were found to be different than those of the fruit accessions used in this study.

According to the descriptive data of *P. laurocerasus* accessions, the 30019, 30028 and 30030 accessions had the highest sphericity means. Conversely, the 20045, 30021, 30042 and 30044 accessions had the lowest sphericity means. While the lowest gravimetric and size means were found at 20043, 30028 and 30030 accessions, these attributes were the highest means for 30023, 30024 and 30027 accessions.

The 20045, 30021 and 30028 accessions had the highest classification rates within own group. This attribute showed that these three accessions was different than the rest of the accessions.

The *P. laurocerasus* accessions were divided into two main distinct groups. The first main group had three subgroups (cluster 1, cluster 2, and cluster 3) and the second main group included two subgroups (cluster 4 and cluster 5). The 30028 and 30025 accessions were in the 1th cluster. The 30019, 30024, 30037, 20028, 30030, 30033, 30029 and 30034 accessions constituted the 2nd cluster. In 3rd cluster, there was only one accession, name of which is 30044. The 30026, 30042, 30039, 30021, 20045 and 30023 were the accessions including in 4th cluster. The 30027, 30022, 30020 and 20043 accessions constituted the last cluster which is 5th.

In regard to the Table 3, the differences among the 30025 and 30028 accessions existing in the 1st cluster were statistically insignificant. The 33.3% of the 30025 accession was involved in the 30028 accession and their Mahalanobis distances were quite small.

In general, it might be concluded that all accessions were similar to the 30034 accession. All these similar accessions in the 2nd cluster located at the right of the canonical discriminant function 1 axis.

It might be seen that the 30044 accession clustered alone in the 3rd cluster and had a small geometric mean diameter and was far from the entire circularity compared with the other accessions in recognition of the descriptive data. Table 3 data showed that the shape attributes of the 30044 accession was akin to those of the other thirteen accessions. Among the accessions, one of the most akin to the 30044 was found to be the 30034. It could be noted in Figure 5b that the 30044 accession located on the canonical discriminant function 1 axis and, out of the other accessions.

The pairwise comparison results showed that accessions in the 4th cluster were quite similar each other. According to the Table 4, the 20045, 30023, 30026, 30039 and 30042 accessions showed a high similarity with the 30021 accession. It could be noted that all genotypes in this cluster located at the left of the canonical discriminant function 1 axis.

The differences among the genotypes in the 5th cluster was insignificant with regard to the results of the pairwise comparison test. It was clearly seen in the Table 4 that the similarity rate of the 20043, 30020 and 30027 accessions was fairly high.

Comparison of clusters in terms of the descriptive attributes. The accessions in the 5th cluster had the highest means with regard to the gravimetric and size parameters. The mass, volume, projected area and geometric mean diameter means of the accessions in the 5th cluster were 4.87 g, 4.82 cm^3, 353.6 mm^2 and 20.7 mm, respectively. But, the lowest gravimetric and size means was obtained from the accessions in the 1st cluster, and their means were determined as 3.15 g, 3.18 cm^3, 259.2 mm^2 and 18.2 mm, respectively. The 1st cluster was the accessions that are the nearest to the entire circularity with the sphericity mean of 96.3%, while the lowest sphericity means with 92.5% observed in accessions in the 4th cluster. It might be concluded that the accessions in the 2nd cluster had the mean values compared with those of the other clusters in terms of the gravimetric and size attributes. The means of the geometric mean diameter, surface area, thickness and width of the 3rd cluster was 18.1 mm, 10.3 cm^2, 16.3 mm and 18.6 mm which are the lowest means, respectively.

CONCLUSIONS

This study concluded the following:

The 30023, 30024 and 30027 were the accessions which had the highest gravimetric and size attributes means while the 20043, 30028 and 30030 accessions had the lowest means.

The closest accessions each other to the entire circularity were 30019, 30028 30030 and 30033. The sphericity means of the 20045, 30021, 30042 and 30044 accessions were the lower than those of the other accessions.

The 20045, 30021 and 30028 were the accessions having the highest classification rates within own group.

The 30028 and 30025 accessions were in the 1th cluster. The 30019, 30024, 30037, 20028, 30030, 30033, 30029 and 30034 accessions constituted the 2nd cluster. In 3rd cluster, there was only one accession, name of which is 30044. The 30026, 30042, 30039, 30021, 20045 and 30023 were the accessions including in 4th cluster. The 30027, 30022, 30020 and 20043 accessions constituted the last cluster which is 5th.

The accessions in the 5th cluster had the highest gravimetric and size attributes than the other accessions. While the accessions in the 1st cluster were the highest sphericity mean and they had the lowest gravimetric and size attributes.

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USTALENIE KSZTAŁTU OWOCÓW LAUROWIŚNI WSCHODNIEJ (*Prunus laurocerasus*) PRZY UŻYCIU ANALIZY ELIPTYCZNEJ FOURIERA

Streszczenie. Laurowiśnia wschodnia (*Prunus laurocerasus*) jest ważną dziką rośliną o jadalnych owocach rosnącą w rejonie Morza Czarnego w Turcji. Określono cechy kształtu dwudziestu dwóch jej odmian, zarówno w sposób opisowy, jak i – po raz pierwszy w literaturze – w oparciu o eliptyczna analizę Fouriera. W ocenie semantycznej kształt większości był zbliżony do kuli, jednak wyniki danych opisowych wykazały różnicę w rozmiarze, kształcie i cechach grawimetrycznych. Odmiany takie jak 30023, 30024 i 30027 miały najwieksze średnie wartości odnoszące się do cech rozmiaru i cech grawimetrycznych, natomiast średnie odmian 20043, 30028 i 30030 były najmiejsze. Dane dotyczące kulistości odmian 30019, 30028, 30030 i 30033 wskazywały na największe średnie mieszczące się w przedziale między 96,2 a 97,8%. Test skupisk podzielił odmiany na pięć podklas. Genotypy w piątym skupisku miały większe wartości cech grawimetrycznych i cech dotyczących kształtu niż pozostałe. Odmiany w pierwszym skupisku miały największą średnią sferyczności, ale najmiejsze wartości cech grawimetrycznych i cech dotyczących kształtu.

Słowa kluczowe: laurowiśnia, analiza Fouriera, kształt, rozmiar

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