GEOMETRIC MORPHOMETRIC ANALYSIS OF THE GRAPEVINE (*VITIS VINIFERA* L.) BERRY SHAPE BY USING ELLIPTIC FOURIER DESCRIPTORS

Grapevine berry shape analysis

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Abstract

Grapevine berry shape has important marketing value in the table grape merchant, hence variability evaluation of this characteristic is highly important. In this study berry shape of 5 table grape genotypes: 'Fanny', 'Lidi', 'Muscat Hamburg', 'Moldova' and 'Orsi' were compared. To evaluate the shape variability graphic reconstruction and geometric morphometric elliptic Fourier analysis have been carried out. Shape outlines have been investigated and PCA has been performed with the SHAPE software package. PCA of the contours showed that 6 out of the 77 principal components were effective to describe shape attributes. The first 6 PCs explained 94.51% of the total variance. PC1 associated with the width and length of the berry. PC2 related to the shape of the bottom of the berries, while PC3 linked to the ratio of the top and the bottom width. ANOVA of the principal component scores revealed significant difference among the genotypes. Results suggest that morphology of the berry differs not only among but within the accessions. Our findings confirmed that Elliptic Fourier Descriptors (EFDs) would be a powerful tool for quantifying grapevine berry morphological diversity.

Keywords: *Vitis vinifera* L., berry, morphology, shape, elliptic Fourier descriptor

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Introduction

Table grape production is a rising sector of agriculture with increasing surface which requires breeding of new cultivars (FAO-OIV, 2016). The most important targets of breeding programs are seedlessness, early ripening, abiotic stress resistance and phenotypic appearance (FERRARA *et al*., 2017). Various berry shape types exist and extreme ones have important marketing value. To define this phenotypic variability descriptor lists have already been developed. PACOTTET (1905) distinguished 5 forms of the berries, while BIOLETTI (1938) classified cultivars into 15 classes. The most widely applied descriptor list given by International Organisation of Vine and Wine (OIV) explains 10 types. It is difficult to precisely define physical form of the berry, therefore reference cultivars are dedicated to each forms. For example, Riesling B has *obloid* berries, Chasselas B has *globose*, while Bicane has *ovoid*, etc. (OIV, 2009). In the case of organs with polygon shape attributes, e.g. leaves, landmarks serve geometric morphometric characterization; contrary the berry shape is sphere or ellipsoid where the definition of homologous points is limited. Elliptic Fourier Descriptors (EFDs) were developed for shape definition of closed contour (KÜHL and GIARDINA, 1982), where a chain-code is obtained from the outline of the object. Using the procedure leaf shape of grapevine accessions have already been described (CHITWOOD *et al*., 2014).

In this study the berry shape of 5 table grape accessions has been investigated with EFD in order to explore morphological variability and define the discriminative characters.

Materials and methods

Berry samples were provided by the Research Institute for Viticulture and Oenology of the National Agricultural Research and Innovation Centre (Kecskemét, Hungary). Grapevine accessions ‘Fanny’, ‘Lidi’, ‘Muscat Hamburg’, ‘Moldova’ and ‘Orsi’ were investigated. Bunches were harvested in 2017 in full ripeness. Twenty berries of each cultivar were collected from several bunches and stored in plastic bags until digitalization. Samples were removed from the clusters and pedicel was nipped at the surface of the berry. Berries were placed on a transilluminating LED light box and digitalized individually with a Sony A58 camera on ISO100. Pictures were then converted into bitmap (BMP) file format. Shape analysis was performed with the SHAPE software package according to the protocol published by IWATA and UKAI (2004). Calculation of the elliptic Fourier coefficients

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according to the chain-code of the contours and analysis of the principal component scores of the provided data was carried out with the corresponding software of the SHAPE package. PCA scores, and 95% ellipses were depicted. Analysis of variance (ANOVA), post hoc test (Tukey) and discriminant analysis (DA) of the PCA scores and cluster analysis based on the mean coordinates of the 95% ellipses were carried out in the PAST 3.12. (HAMMER *et al*. 2001). Digital reconstruction of the main shape types along the first 6 PCA was carried out in the SHAPE (IWATA and UKAI, 2004).

Results

PCA of the contours showed that 6 out of the 77 principal components were effective to describe shape attributes. The first 6 PC explained 94.51% of the total variance. PC1, PC2 and PC3 described 78.01%, 6.10% and 4.67% respectively. PC1 associated with the width and length of the berry samples. Higher value of the PC1 are associated with the more obloid, lower values with more elongated berries. PC2 is related to the shape of the bottom of the berries, while PC3 is linked to the ratio of the top and the bottom width. Plotting the coordinates along PC1 and PC3 showed that 'Orsi' has more elongated berries, while 'Fanny' has more obloid ones. Among the samples 'Moldova' has wider berries on the top, while 'Orsi' has on the bottom (Figure 1).

ANOVA revealed significant difference among berry morphological characteristics of the accessions. Three out of the 6 effective principal components were significantly different among the samples at $p<0.001$ level (PC1: $F(4,95) = 42.23$, $p<0,0001$; PC2: $F(4,95) = 5.55$, $p<0.001$; PC3: $F(4,95) = 13.52$, $p<0.0001$).

Size of the ellipses including 95 % of the samples belonging to the same cultivar showed that 'Lidi' has the highest morphological diversity along the PC1 and PC3, while the most uniform berry shape is observed at 'Fanny'. Morphological similarity among the cultivars has been calculated by the mean x-y coordinates of the ellipses of each. Hierarchical clustering based on the Euclidean distance (Cophen. Corel: 0.81) showed that 'Lidi' and 'Muscat Hamburg' are the most similar in berry shape, while the most different are 'Orsi' and 'Fanny' (Figure 2). Discriminant analysis of the PCA scores reached 69% correct classification (Jackknifed). The highest and the lowest success of classification were obtained in the case of Orsi and Lidi with 85% and 15% respectively.

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Discussion

To describe and distinguish grapevine species and cultivars berry morphology has been in the focus of morphological characterization from the very beginnings. WORLIDGE (1691) has already mentioned the importance of berry size. CLEMENTE (1807) classified the cultivars among others based on the berry shape. Reference shapes have been included in the ampelographic literatures to help description of the genotypes (LAUCHE AND GOETHE, 1894). During the 20th Century with the help of photography new techniques were introduced in ampelography. RODRIGUES (1953) for example used photograms to describe shape diversity. In this study we recorded berry phenotype with digital photography.

Despite of the importance of berry shape its metric description (a.k.a. *uvometry*) is still come down to the measurement of the *width* and *length* or the ratio of these two, which is usually referred as the *berry shape index*. For example, EL-SAYED (2013) reported data about the Crimson Seedless grapevine berry shape based on this index. There are numerous scientific papers reporting about shape attributes of object with closed contour. One of the possible methods is the characterization based on elliptic Fourier descriptors. The process was introduced by KUHL AND GIORDINA (1982) and later applied in ampelography by DIAZ *et al*. (1991) and CHITWOOD *et al*. (2014). In this study berry shape has been described by the method.

Results of this study showed that the berry shape is differing significantly among the genotypes. Also the variability of the shape within the same genotype was not the same. This result is in accordance with the literature. KOZMA (1965) mentioned that some of the cultivars have more uniform berry shape while others have more variable. We found that 'Lidi' has the highest morphological diversity while 'Fanny' has the lowest. We think that the berry shape variability is an important phenomenon when evaluation of the consumer's preference is carried out.

Conclusions

Grapevine berry shape is a variable morphological pattern which description requires routine and reference cultivars. Our findings confirmed that EFD would be a powerful tool for quantifying berry morphological diversity.

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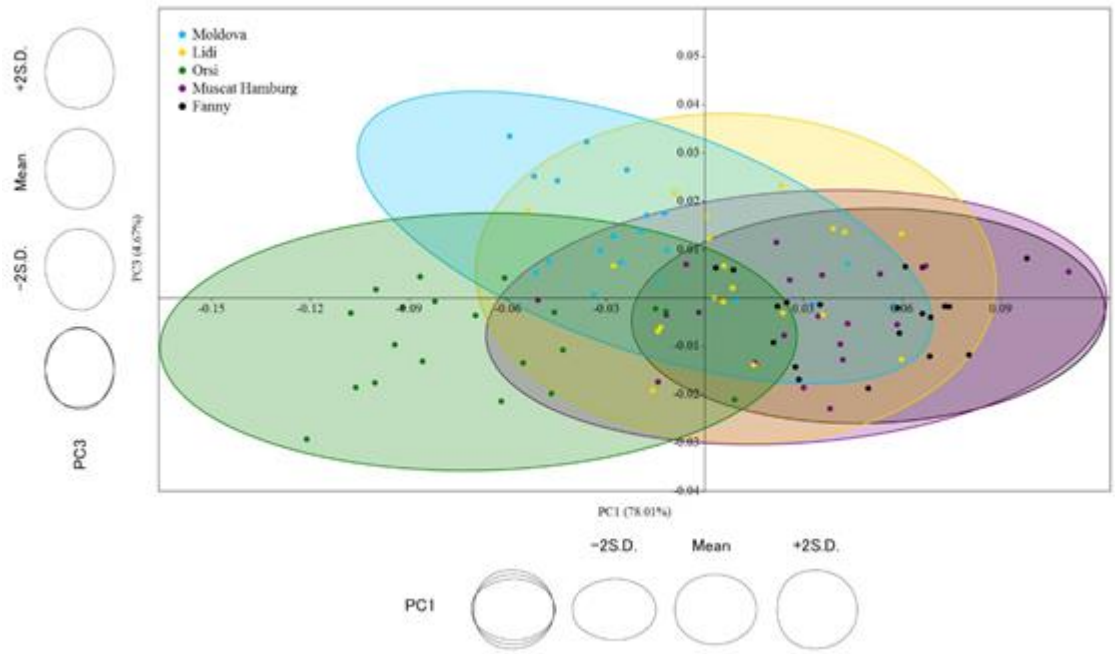

Figure 1: PCA scores and berry shape reconstruction along PC1 and PC3

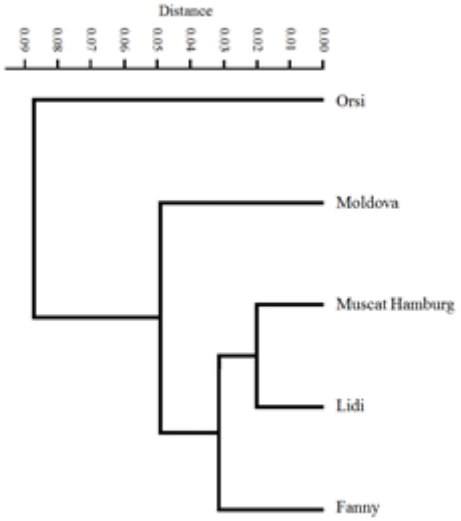

Figure 2: Hierarchical clustering based on the Euclidean distance of the mean coordinates of the 95% concentration ellipses along PC1 and PC3

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