Theses of the doctoral thesis

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# UVOMETRIC DESCRIPTION OF GRAPEVINE VARIETIES AND DEVELOPMENT OF TESTING METHODOLOGY

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# 1 INTRODUCTION AND AIMS OF THE STUDY

Fruit species have many quality parameters, with consumers being influenced by size, color and shape (PREDIERI et al., 2004). According to a 2017 survey by WANG et al. in China, consumers prefer grape varieties with round berry shapes, but ZHOU et al. in 2015 found that consumers choose grape varieties with oval berries. The evolution of varietal choice in Hungary shows a similar trend, with mostly round and oval berry varieties on the market (BARNA, 2023).

The description of berry size appeared in the literature as early as the 16th century. SZIKSZAI (1590) mentions the 'uva spionia' ('large-eyed grape' = grape with a large berry). PARKINSON (1650) uses the term 'small black grape', which, according to the illustration, referred to the size of the berry. Nowadays, both ampelographic albums and technical articles (BARBAGALLO et al., 2011) and official guides such as the OIV (2009) descriptor guide provide details of the berry size classes.

In recent years, a number of image analysis software have been developed to offers the potencial the morphological characterisation of horticultural plant organs. The 'Tomato Analyzer' (TA) evaluates area and perimeter, maximum width and height, width at mid-height and height at mid-width of tomato berries. The software can also evaluate different shape indices and describe the asymmetry of the fruit (RODRÍGUEZ et al., 2010).

Other forward-looking methods are the closed contour-based techniques. Elliptic Fourier Descriptors (EFDs) are also used to describe shapes, where only the contour of the studied object bears information (KÜHL and GIARDINA, 1982).

In our work, we investigated the applicability of digital image analysis methods to amphelography and the influence of different factors on the variability of berry shapes. We aimed to answer the following questions:

- Do canopy management practices i.e. cluster thinning applied in viticulture influence morphological characteristics of the berry?
- Does vintage influence grapevine berry shape?
- Do different locations influence the morphology of the fruit?
- Does seed number influence the uvometric characteristics?

- To what extent is there intra-cluster variability in berry shape?

## 2 MATERIALS AND METHODS

Samples for our research were collected from the following locations between 2017 and 2020:

- for our preliminary experiment, the Fehérvár Markethall
- the MATE SZBI Kecskemét variety collection,
- Kun Szőlő Családi Gazdaság in Kővágótöttös,
- from the area of a family plantation in Legyesbénye.

In the preliminary experiment, two samples without variety denomination with different berry morphology were tested. In order to study the effect of canopy management treatments, cluster thinning was carried out at three different time points (at setting, at *veraison*, at ripening) to observe their effect on the berry morphology of *Vitis vinifera* L. cv. 'Italia' and the effect of two different growing sites on berry shape variability was analyzed for 'Italia'. To investigate the effect of vintage, the berry morphology of 46 different grape varieties (Table 1) was studied in three consecutive years.

Table 1: 46 grapevine varieties used in the vintage effect study.

| | | | | |
|---|---|---|---|---|
| '13/2' | Cirfandli | KM238 | Olasz rizling | Sztrasenszkij |
| '13/5' | Csokonai | KM249 | Palatina | Trollingi kék |
| Admirable de Courtiller | Erzsébet királyné emléke | KM95 | Pannónia kincse | Urozsajnüj |
| Agata | Eszter | Malaga kék | Perlette | Usztojcsivüj gyikij |
| Boglárka | Irsai Olivér | Mathiász Ernőné | Pölöskei muskotály | Viktória gyöngye |
| Bouvier | Italia | Mátrai muskotály | R12 | Vitis typ Weis |
| Cabernet sauvignon | Karola | Merlot | R24 | |
| Cardinal | Kékfrankos | Mikszáth | R80 | |
| Chardonnay | Kismis moldavszkij | Moldova | Rajnai rizling | |
| Chasselas | KM144 | Muscat Bouschet | Ruszbol | |

To describe the morphological variability within the cluster, 5 grape varieties were used: 'Belüj originalnüj', 'Dunav', 'Guzal kara', 'Moldova' and 'Souvenir'.

For our traditional morphometric analyses, 13 varieties were selected: '13/2', 'Cornichon-szerű, 'Ferencz József', Gyűszű szőlő', ’Halhólyag fehér’, 'Italia', 'KM.193', 'KM.238', 'Mecsta', 'Perlona', ’Szusenszkij belüj’, ’Usztojcsivüj gyikij’ and 'Vitis typ. Weiss'.

For the sub-experiments 'Preliminary experiment', 'Effect of the Canopy Management on Berry Shape', 'Variability of Berry as a Function of Vintage' and 'Analysis of Berry Shape in Different Parts of the Cluster', the digitization of the samples was carried out in the same way in all cases. The berries were carefully removed from the clusters and the pedicels were cut off. The samples were digitized on a transilluminated table with LED light source using a Sony A58 digital camera. Images were processed using the Shape software package following the protocol provided by IWATA and UKAI (2004).

For the traditional morphometric analyses, the selected berries were counted, and the pedicels were carefully removed. The weight of the samples was individually weighed on an Ohaus Explorer analytical balance, then the berries were halved. The seeds of the halved berries were counted and recorded. One section per berry was digitized using an Epson V370 scanner at 200 dpi resolution.

In all cases, statistical evaluation was performed using the PAST 3.12 software (HAMMER et al., 2001).

## 3 RESULTS AND DISCUSSION

### 3.1 Preliminary Experiment

After preparation and digitization of the 254 berries, the principal component analysis found 77 principal components (PCs), of which 6 effective PCs were extracted. PC1 was related to width and length, with higher PC1 values indicating a more rounded shape and lower values indicating a more elongated shape. The PC2 value indicated the shape of the lower half of the berries, while PC3 indicated the ratio of the width of the upper and lower thirds. The result of principal component analysis showed that the two phenotypes were different with slight similarities. The data were plotted in coordinate system with 95% ellipses fitted, showing that there is minimal overlap between the patterns.

In a preliminary experiment of contour analysis, we have demonstrated the effectiveness of elliptic Fourier descriptors in determining berry shapes.

### 3.2 Effect of the Canopy Management on the Berry Shape

Berries from the first and third thinned bunches and from the top and middle thirds of the control group were more elongated, while those from the second thinned bunches were more rounded. A two-factor ANOVA showed that PC1 values were significantly influenced by berry location within the cluster and by the time of cluster thinning, but these two factors were not related. PC2 values were only influenced by the time of cluster pruning, while the location within the cluster had no effect on the values. Neither PC3 nor PC4 values were influenced by the time of phytotechnical treatments or the position of the berry

The results of the study showed that the morphology of the berries differed in the top, middle and bottom parts of the cluster. This morphological variability has been described previously.

BIOLETTI (1938) observed that varieties with more extreme berry shapes are more variable within a cluster. Depending on the timing and the extent of thinning, cluster thinning causes variation in yield and berry weight (FITZGERALD and PATTERSON, 1994). In this study, we observed that treatments also had an effect on berry shape. The latest thinning (at maturity) increases the morphological variation of the berries. Our experiment proves that digital image analysis is a suitable tool to detect differences in berry shape.

### 3.3 Variability of Berry Shape as a Function of Vintage

The morphological evaluation of the berries of 46 genotypes carried out in three consecutive years shows that there is considerable variability in berry shape within a variety. In our work, the OIV (2009) descriptor key was also included, and reference berry shapes were drawn according to the broad ellipsoid, cylindrical, finger-shaped, globose, horn-shaped, narrow ellipsoid, ovoid, ovate, obtuse ovoid, obloid shapes.

Variability within varieties is a well-known phenomenon, already noted by KOZMA (1968). This inhomogenity may have caused the LDA to show low efficiency in correctly grouping samples. The highest correct classification (59.52%) was observed for '13/2', while the overall correct classification was 13.88%. This result confirms that berry shape is not only a variable trait between genotypes but also within genotypes, which is not uniform even in three consecutive years.

### 3.4 Influence of Growing Site on the Uvometric Characteristics of the 'Italia' Grapevine Variety

'Italia' is one of the most important and most studied table grape varieties. 'Italia' has a number of somatic mutants which, through selection, have resulted in new varieties with diverse morphological characteristics (MAIA et al., 2009). In this study, we found that the berry size of the 'Italia' cultivar ranges from medium to large. In the 'Tomato Analyzer' it is possible to examine the width at mid- height and at the widest position. In the case of 'Italia', there is little difference between these data, but the shape of the berries is not spherical in many varieties, but ellipsoidal, obovoid, ovoid or, in extreme cases, horn-shaped or finger-shaped. In these latter categories, the size characteristics measured in different positions can vary considerably. Accordingly, it would be important to emphasize in the descriptions and in the adverbs which position the width of the berry is measured in.

The size of the grape berry varies during development according to a double sigmoid curve. The final size depends on the variety (BÉNYEI and LŐRINCZ, 2005), the bud load adjusted during pruning (INTRIERI et al., 2001), specific canopy management practices (CARRENO et al., 1998) or, for example, the number of seeds. Grapevine berries usually have 1 to 4 seeds, but seedless berries and berries with 5 seeds have also been found. In our tests, we found that 6.04% of the samples had no seeds, while the majority of berries had 1 or 2 seeds (37.58% and 33.89%), which is in agreement with the finding of SABIR (2011) that the number of seeds per berry varies between 1.84 and 1.98. Calculation of berry size characteristics provides primary data (width, length), but additional data can also help in calculating surface area. Image analysis of berry size characteristics may also be a possible way to measure skin surface area.

Our studies show that the number of seeds significantly influences the berry size of the 'Italia' variety, but the two growing sites did not significantly influence the berry shape.

### 3.5 Analysis of Berry Shape in Different Parts of the Cluster

In the present study, 5 grape varieties were included, for some varieties no difference in intra-cluster variability of berry shape was observed ('Belüj originalnüj', 'Moldova'), while for other varieties this difference was striking ('Dunav', 'Guzal kara', 'Szuvenir'). The results are in line with previous findings that there is a significant difference in the diversity of berry shape between varieties (KOZMA 1968).

### 3.6 Traditional Morphometry

In this study, we found that there are obvious differences between berry samples of the same genotype, and this variation is strongly influenced by seed number. Discriminant analysis highlighted those traits that provide a high level of correct classification between samples, but our results showed that the discriminant potential of berry shape and size traits was associated with particular similarity groups of varieties rather than individual genotypes. We conclude that digital image analysis is an effective tool for evaluating diversity in berry size and shape, and that the 'Tomato Analyzer' can be successfully applied to large sample sizes in ampelography. This method provides a time-saving and accurate description of samples, providing valuable information on uvometric diversity.

## 4 NEW SCIENTIFIC RESULTS

1. I have demonstrated that the use of elliptic Fourier descriptors is a suitable method for assessing berry morphological variability in grapevine varieties and that traditional digital morphometric analyses can also be used effectively in uvological analyses.

2. Based on my results, I have found that berries from 'Italia' vines treated with cluster thinning at different times have different berry morphology. This variability is further enhanced by intra-cluster diversity.

3. I have found that in the case of 'Belüj originalnüj', 'Dunav', 'Guzal kara', 'Moldova', 'Souvenir', the lower, middle and upper berries within the cluster show significant variation in shape.

4. I found that berry size of the 'Italia' cultivar was not significantly influenced by growing site, but berry shape was, and that berry seed number significantly influenced both shape and size.

5. Based on a 3-year shape analysis of 46 grape varieties, I found that the vintage effect had a significant influence on berry shape. A system was developed to compare the samples with the OIV reference shapes.

6. In traditional morphometric studies, I have found that berry shape is a characteristic of groups of varieties rather than a specific attribute to individual varieties.

# 5 PUBLICATIONS

Basic Requirements

Scientific publications with impact factors

**Somogyi, E**., Varga, Zs., Pisák, F., Bálo, B., Bodor, P. (2019): The effect of cluster thinning on berry shape of Vitis vinifera L. cv. ‚Italia‘. *Mitteilungen Klosterneuburg*. 69(4) pp 216-222.

**Somogyi, E.**, Lázár, J., Baranyai, L., Bodor- Pesti, P., Nyitrainé Sárdy, D., Á. (2022): Outline analysis of the grapevine (Vitis vinifera L.) berry shape by elliptic Fourier descriptors. *Vitis*. 61(2) pp 63-70.

Refereed scientific publications without impact factors

Bodor- Pesti, P., **Somogyi, E**., Deák, T., Nyitrainé Sárdy, D., Á., Ladányi, M. (2022): Quantitative image analysis of berry size and berry shape of different grapevine (Vitis vinifera L.) accessions. *Mitteilungen Klosterneuburg.* 72 (2) pp 130-136.

Further scientific publications with impact factors (beyond the basic requirements):

Nagy, A., Nyitrainé Sárdy, D., Á., Ladányi, M., Bodor, P., Fazekas, I., **Somogyi, E**., Bálo, B. (2021): Effect of Early Leaf Removal and the Characteristics of the Vineyards on Grapevine (*Vitis vinifera* L.) Cultivar 'Zweigelt' in Different Sites. *Mitteilungen Klosterneuburg*.71 (2) pp 156-169

**Somogyi, E**., Lázár, J., Bodor, P., Kaszab, T. (2020): Colour of grapevine (Vitis vinifera L.) accessions influenced by the length of cold storage. *Progress in Agricultural Engineering Sciences*. 16 (2) pp 109-116.

Bodor, P., **Somogyi, E.**, Baranyai, L., Lázár, J., Bálo, B. (2020): Analysis of the grapevine (Vitis vinifera L.) berry shape by using elliptic Fourier descriptors. *Progress in Agricultural Engineering Sciences*.16 (1) pp 87-93.

Further scientific publications

Bodor, P., **Somogyi, E.**, Bálo, B. (2018): A szőlőbogyó-repedés lehetséges okai. *Agrofórum Extra*. 76. pp 36-37.

Bodor- Pesti, P., **Somogyi, E.**, Varga, Zs. (2022): Digital image analysis methods in grapevine uvometric investigations, *Hungarian Agricultural Research: Environmental Management, Land Use, Biodiversity*. 32 (4) pp 4-8

Conference proceedings:

Bodor, P., **Somogyi, E**., Baranyai, L., Bálo, B. (2018): Grapevine berry phenotyping by using elliptic Fourier descriptors. *PREGA Science Conference*. Budapest. 20 February 2018. ISBN: 9786150030449

Bodor, P., **Somogyi, E**., Baranyai, L., Lázár, J., Bálo, B. (2018): Geometric morphometric analysis of the grapevine (Vitis vinifera L.) berry shape by using elliptic Fourier descriptors. *2nd International Conference on Biosystems and Food Engineering.* Budapest. 8 June 2018. ISBN 978-963-269-753-6.

**Somogyi, E**., Kun, Á., Lázár, J., Bodor- Pesti, P., Nyitrainé Sárdy, D., Á. (2021): Quantitative analysis of the berry size in grapevine cultivar 'Italia'. *4th International Conference on Biosystems and Food Engineering : Book of Abstracts.* Budapest, 2021.06.04. - 2021.06.04. E442. 8 p.

**Somogyi, E**., Lázár, J., Bodor, P., Kaszab, T. (2019): Color of table grape accessions influenced by the length of cold storage. In: Zsomné Muha Viktória, Márki Edit , Baranyai László (szerk.): *BiosysFoodEng 2019 - Proceedings: 3rd International Conference on Biosystems and Food Engineering.* Budapest, 2019.12.04. - 2019.12.04. p. E352. ISBN: 9789632698786

**Somogyi E**., Kun Á., Bálo B., Bodor P. (2019): Csemegeszőlő fajták uvometriai értékelése. In: Karsai Ildikó (szerk.) *Növénynemesítés a 21. század elején: kihívások és válaszok: XXV. Növénynemesítési Tudományos Nap.* Budapest, 2019.03.06. - 2019.03.07. pp 441-444. ISBN: 9789638351456

Conference abstracts:

Bodor- Pesti, P., Varga, L., **Somogyi, E.**, Varga, Zs. (2021): Az uvometriai vizsgálatok fejlesztési lehetőségei a digitális képalkotás segítségével. In: Fodor Marietta, Bodor-Pesti Péter, Deák Tamás (szerk.):*Lippay János – Ormos Imre – Vas Károly (LOV) Tudományos Ülésszak: Összefoglalók*. Budapest, 2021.11.29. p. 30. ISBN: 9786150137384

Bodor, P., **Somogyi, E.,** Varga, Zs., Bálo, B. (2018): Klimatikus okok a szőlő bogyórepedésének hátterében. In: Puskás

J (szerk.): *10. Szőlő és Klíma Konferencia: Program és az előadások összefoglalói.* Kőszeg, 2018.04.13. - 2018.04.14. pp 11-11