Charecterisation of morphological properties of apricot stones by image processing

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Abstract: *The morphological characteristics of the apricot stones of different cultivars show much higher variability, as it is typical in case of other fruit species. The variety of forms is easy to observe sensorially (directly or using a reading-glass), however it's hard to describe exactly, in a quantitative way. The widely accepted international standard is based on comparison with standard cultivars, the results are given in a special point system, developed for this purpose. The information, provided by this evaluation system is not suitable for identification of the cultivars, but it can be used for distinguishing two sample sets. The aim of our research work was to develop quantitative methods for description of the stones. The statistically validated quantitative parameters offer the possibility of applying them as morphological markers for identification of the cultivars or for other genetic analyses without leaning on any standard samples as references. The traditional measurement methods are able to determine only the simplest geometrical parameters of the samples (such as length, width or thickness). However, the special characteristics, connected to the different cultivars, are related to much more complex shape parameters. Computer based machine vision system and image processing was applied for quick, automatic shape feature extraction and determination of new, quantitative shape characteristics.*

1 Introduction

The apricot 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. Distillates and wines are made from both cultivated and non-domesticated apricot both in Europe and Asia (JOSHI *et al.* 1990, GENOVESE *et al.* 2004).

The early botanical descriptions of the different apricot species were based primarily on leaf shape and pubescence, and these characters were not always consistent between specimens. Bailey's (BAILEY 1916) categorical distinctions of apricot species and botanical varieties used leaf characteristics. Even the taxonomy of apricots by Chinese investigators was also based mainly on leaf characteristics (HOU 1983). The classification by Rehder (REHDER 1940) distinguished plums from apricots on the basis of ovary pubescence, being absent or glabrous in the plums and present or pubescent in apricots.

Studying the relevant characteristics of distinct species or pomological/botanical varieties are more and more important for breeding and other particular classification purposes (ASMA & OZTURK 2005, BADENES *et al.* 1998).

The morphological characteristics of the apricot stones of different cultivars show much higher variability, as it is typical in case of other fruit species. The variety of forms is easy to observe sensorially (directly or using a reading-glass), however it's hard to describe exactly, in a quantitative way. The widely accepted international standard (UPOV 2008, IPGRI 1980) is based on comparison with standard cultivars, the results are given in a special point system, developed for this purpose. The information, provided by this evaluation system is not suitable for identification of the cultivars, but it can be used for distinguishing two sample sets.

The aim of our research work was to develop quantitative methods for description of the stones. The statistically validated quantitative parameters offer the possibility of applying them as morphological markers for identification of the cultivars or for other genetic analyses without leaning on any standard samples as references.

The traditional measurement methods are able to determine only the simplest geometrical parameters of the samples (such as length, width or thickness). However, the special characteristics, connected to the different cultivars, are related to much more complex shape parameters. Computer based machine vision system and image processing was applied for quick, automatic shape feature extraction and determination of new, quantitative shape characteristics.

2 Materials and methods

The base of the tests was the collection of the Genetika és Növénynemesítés Tanszék containing the stones of approximately 300 sample sets (all Hungarian cultivars, important foreign cultivars and hybrid families needed for genetic analyses). The sample sets are represented by 14-20 stone samples. For the development of the methods, six hybrid samples of definitely distinct morphological properties were selected (**Figure 1**).

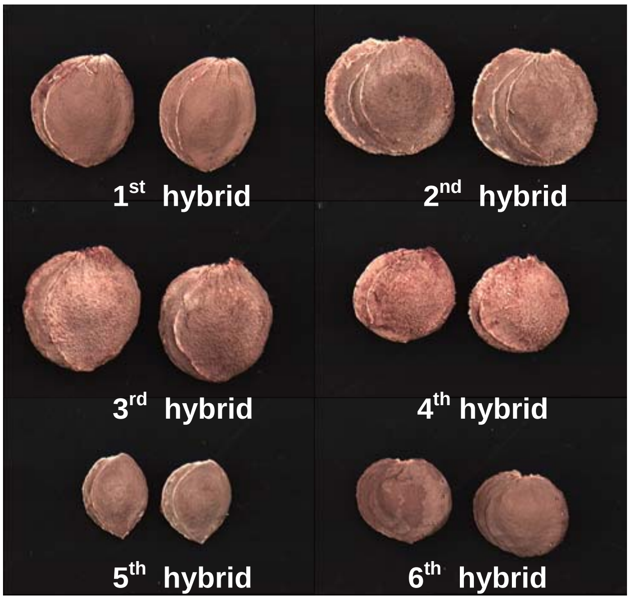

Figure 1: Stone samples of tested hybrid cultivars

The digital images were recorded by a Hitachi HV-C20 professional, 3-chip CCD camera, fitted to a PC via an add-on card for frame grabbing. The recorded images were stored in a 768 x 576 resolution, true-colour bitmap file for the further assessment.

Special diffuse lighting system was applied for taking the photos, were the samples were illuminated only by reflected light. The images were recorded in 4 different setups for all samples (**Figure 2**):

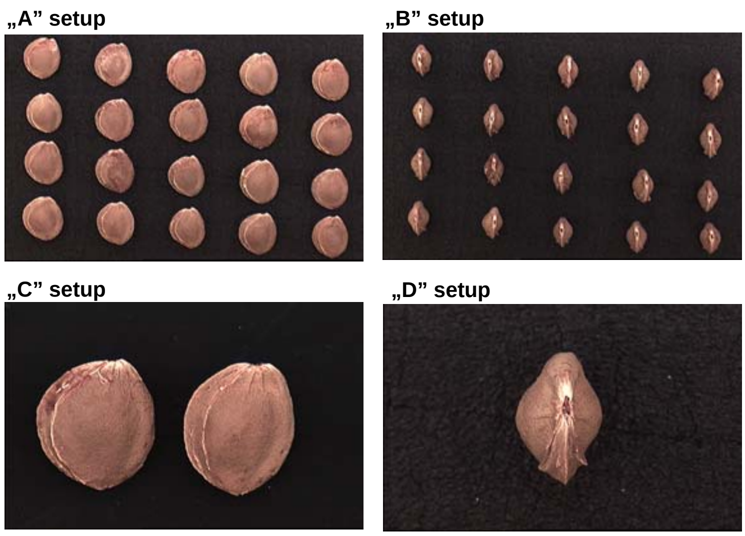

Figure 2: Image recording setup

„A" setup: stones in side view – 14-20 stones of one hybrid on one picture
„B" setup: stones in top view – 14-20 stones of one hybrid on one picture
„C" setup: stones in side view – magnified images of 2-2 stones per hybrid on one picture (for investigation of the surface texture properties)
„D" setup: stone in top view – magnified image of 1-1 stones per hybrid on one picture (for investigation of the crest-like formation on the side part of the stones)

The recorded images were analysed with a special image processing software (FFImgPro), developed at the Department of Physics and Control of CUB). The algorithm is for segmentation of the objects and the background according to the statistical analysis of their colour properties, for determination of the area and average RGB colour parameters of the objects and for saving the data into a file. Also, the co-ordinates of the border-points of the objects are determined, and stored for shape assessment. The quantitative shape was performed by the “Shape” software (FELFOLDI 2000). The algorithm determines the following geometrical parameters:

- length of the stone
- maximum width of the stone
- position of the maximum diameter along the longitudinal axis (0 .. 1)

The geometrical results are given in pixel-number or – after calibration – in mm. The main advantage of the image processing methods is the possibility of determination of new, quantitative and objective shape characteristics by analysis of the shape data. In the research work, presented here the periodicity parameters of the outline functions (related to the main symmetry properties of the stones) were taken into investigation. These parameters can be determined by Fast Fourier Transformation (FFT) of the outlines and the FFT components can be connected to definite symmetries, e.g.:

- FFT2: elliptic shape
- FFT3: triangle-like shape
- FFT4: quadratic shape, …

For statistical analysis of the results Excel, and SPSS for Windows (Ver. 10.0) software were used.

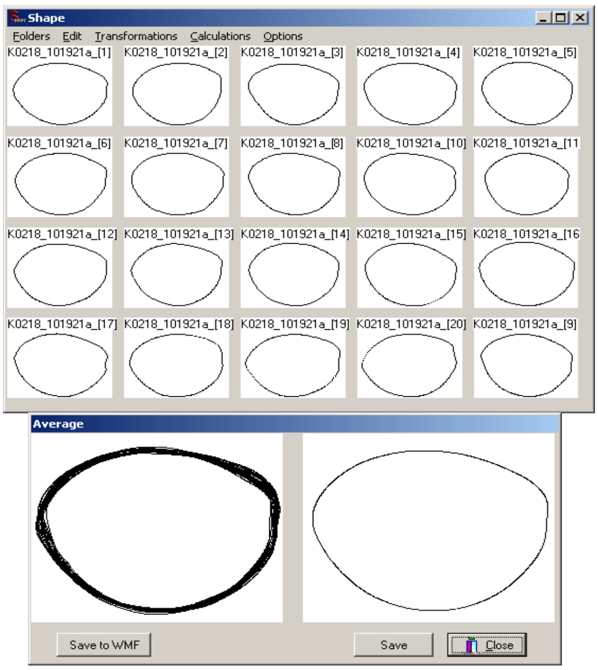

Figure 3: Outlines of the samples of 1st hybrid (20 pieces) and averaged outline, characteristic for the hybrid

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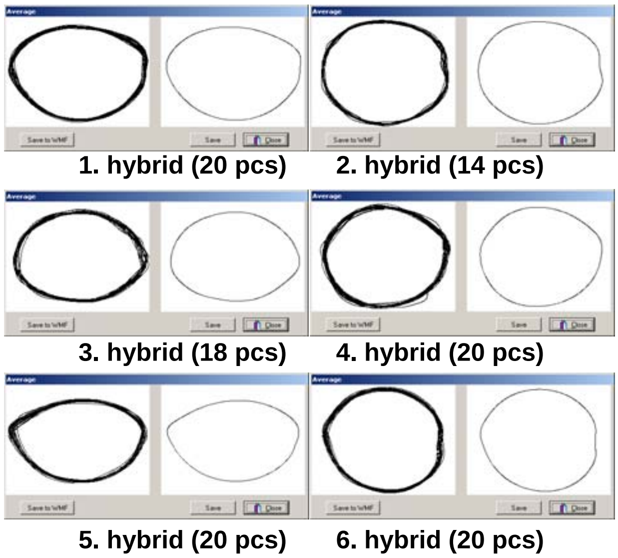


Figure 4: Averaged outlines of the tested hybrids

3 Results

ANOVA

One factor analysis of variance was used for statistical comparison of the main geometrical parameters of the tested stone samples (length and width). These parameters alone were not enough for unambiguous separation of the hybrid sample groups. The results are illustrated on **Figure 5**, showing the average values of the tested parameters with their 95% confidence interval.

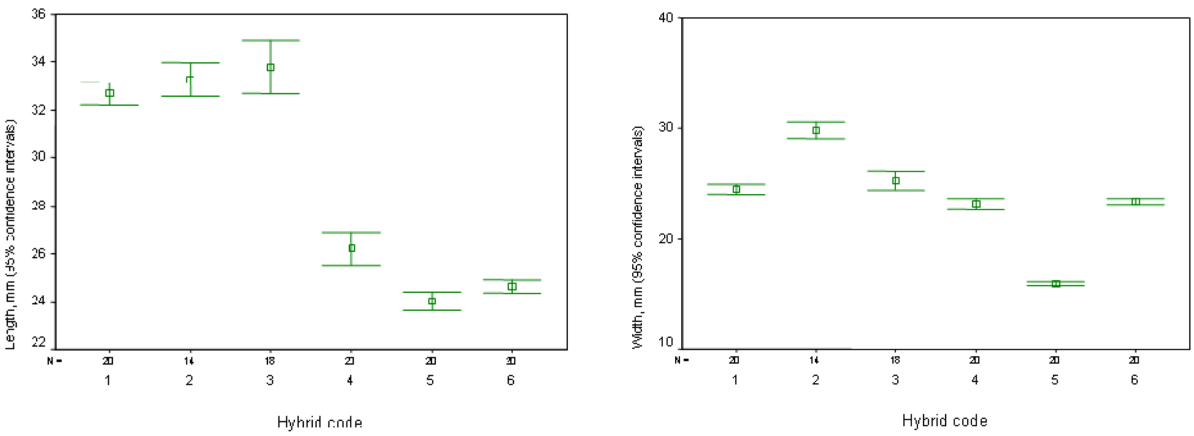


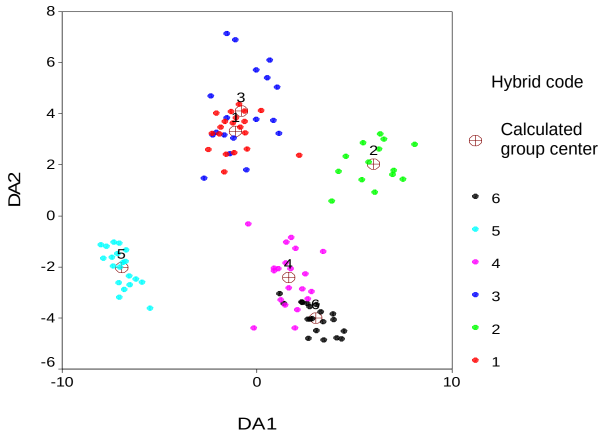
Figure 5: Confidence intervals of length (a) and width (b) parameter of hybrids

Discriminant Analysis (DA) including more quantitative parameters

1. DA of the length and width: only the 2nd and 5th hybrids are separated from each other, the other four hybrids are not distinguishable according to these parameters (**Figure 6**)

2. DA of shape characteristics: besides the geometrical parameters (length and width) the FFT components of the outline function were included as well. In this case, four hybrids (1st, 2nd, 5th and 6th) can be distinguished perfectly, however this information was not effective enough for separation of the further 2 sample sets (**Figure 7**)

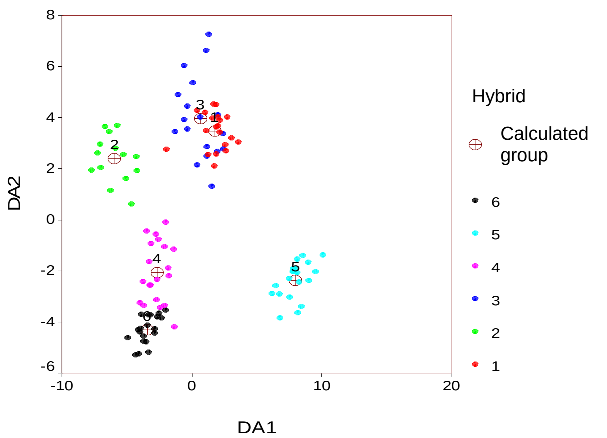
3. DA of shape and colour characteristics: the average colour components of the samples were added to the parameters used in previous investigation. This analysis provided with 100% perfect separation of every hybrid included in the test (**Figure 8**).



Result of Classification

Hybrid code	Calculated class 1	2	3	4	5	6	Total	
1	14	0	6	0	0	0	20	piece
2	0	14	0	0	0	0	14	
3	8	0	10	0	0	0	18	
4	0	0	0	16	0	4	20	
5	0	0	0	0	20	0	20	
6	0	0	0	2	0	18	20	
1	70	0	30	0	0	0	100	%
2	0	100	0	0	0	0	100	
3	44,4	0,0	55,6	0	0	0	100	
4	0	0	0	80	0	20	100	
5	0	0	0	0	100	0	100	
6	0	0	0	10	0	90	100	

Figure 6: Separation of the tested hybrids according to Discriminant Analysis of their length and width parameters



Result of Classification

Hybrid code	Calculated class 1	2	3	4	5	6	Total	
1	20	0	0	0	0	0	20	piece
2	0	14	0	0	0	0	14	
3	1	0	17	0	0	0	18	
4	0	0	0	19	0	1	20	
5	0	0	0	0	20	0	20	
6	0	0	0	0	0	20	20	
1	100	0	0	0	0	0	100	%
2	0	100	0	0	0	0	100	
3	5,6	0	94,4	0	0	0	100	
4	0	0	0	95	0	5	100	
5	0	0	0	0	100	0	100	
6	0	0	0	0	0	100	100	

Figure 7: Separation of the tested hybrids according to Discriminant Analysis of their shape characteristics

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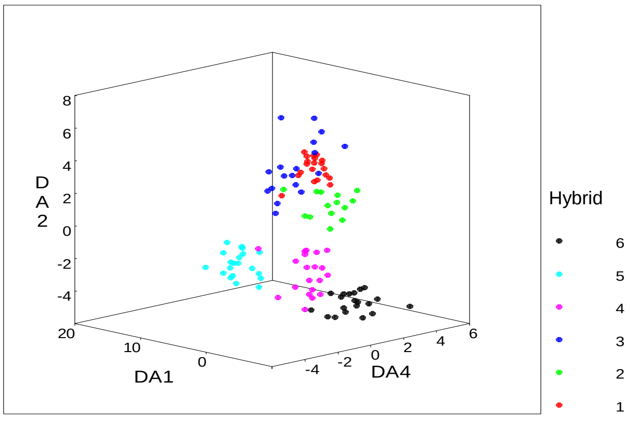

Result of Classification

Hybrid code	Calculated class						Total	
	1	2	3	4	5	6		
1	20	0	0	0	0	0	20	piece
2	0	14	0	0	0	0	14	
3	0	0	18	0	0	0	18	
4	0	0	0	20	0	0	20	
5	0	0	0	0	20	0	20	
6	0	0	0	0	0	20	20	
1	100	0	0	0	0	0	100	%
2	0	100	0	0	0	0	100	
3	0	0	100	0	0	0	100	
4	0	0	0	100	0	0	100	
5	0	0	0	0	100	0	100	
6	0	0	0	0	0	100	100	

Figure 8: Separation of the tested hybrids according to Discriminant Analysis of their shape and colour characteristics

In further investigations, more samples (hybrids) with less different morphological characteristics will be tested. To increase the efficiencies of the image processing classification method, quantitative description and statistical analysis of new parameters planned to take into account (characterisation of the surface texture, belonging to the given cultivars) and the number, size and position of the crest-like formations on the side part of the stones) (**Figure 9** and **10**).

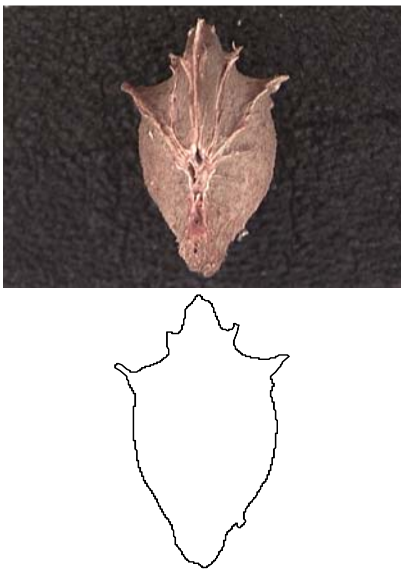

Figure 9: Machine vision representation of the crest-like formation on the side part of the stones

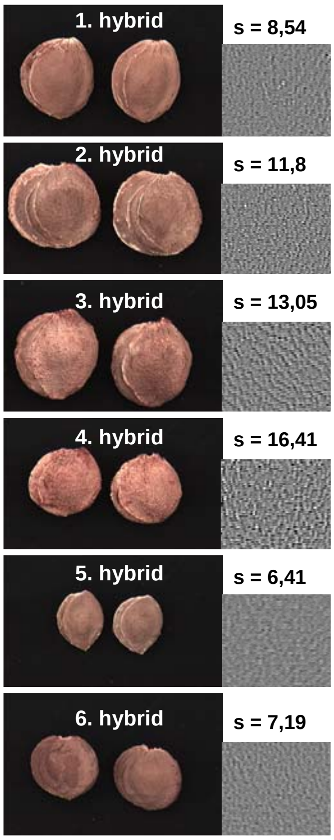

Figure 10: Quantitative description of the surface texture (roughness) of the tested hybrids based on standard deviation of the equalised grayscale surface image

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