Identification of Potato Genotypes Using Digital Image Analysis

Burgonya fajták azonosítása és minősítése digitális képanalízis felhasználásával

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ABSTRACT

Based on the fractal analysis of digital images, a new classifying system has been proposed at the Potato Research Centre of Keszthely. It is a qualifying system generating objective values to distinguish potato varieties or detect quality differences within the genotype in a relatively simple way.

The goal of the research project was to investigate whether Spectral Fractal Dimension (SFD) value of digital images is applicable to describe various quality characters of potato tubers and whether SFD values could be used for the identification of certain varieties – if so, which conditions were the most important to enable this process.

Considering the above aims, we developed an evaluation computer program which determines the SFD values of the 4 conditions of potato tubers: skin colour; raw flesh-colour; boiled flesh-colour; greying of flesh-colour after 24 hours in RGB spectrum and in all of its sub-spectrums (R, G, B). In total 2080 digital images of 13 varieties from 4 examining periods were analysed.

Based on our results we can conclude that SFD analysis can be used in potato breeding only when digital images were made under well-determined, standardized conditions.

Detailed statistical analysis (hypothesis tests, principal component analysis and non-hierarchic cluster analysis) showed that SFD was not suitable for qualifying tuber characters within a genotype. When images were examined for different years and the same genotype, it became evident, that there are significant deviations between years and within same genotypes. We could conclude that the identification of genotypes should be related not to one particular SFD value, but to the control of the given year with the known value.

When analyzing the differences between genotypes on yearly basis, irrespective of characteristics or the studied spectrum, we could not significantly separate genotypes, although there were some that could be separated, even though genotypes and their characteristics changed every year. It cannot be stated either that by combination of the values of different characteristics and spectrums, separation is not possible. We used non-hierarchic cluster analysis to solve this problem. As a result of the method, the separation of genotypes was successful every year, so by summarising the joint RGB SFD value of 4 characters with the values of additional spectrum the separation will be complete.

The system could be utilized for research purposes and further research is needed to achieve practical applicability.

Keywords: digital image analysis, fractal, spectral fractal dimension, potato breeding, genotype identification, cluster analysis, non-hierarchic cluster analysis

Összefoglalás

A keszthelyi Burgonyakutatási Központban egy a digitális képek fraktál analízisén alapuló olyan objektív értékeket adó, új minősítési rendszer került kifejlesztésre, amely vagy a burgonyafajták elkülönítését vagy a fajtán belüli minőségi különbségeket képes viszonylag egyszerűen és gazdaságosan kimutatni.

A kutatás célul tűzte ki annak vizsgálatát, hogy, alkalmazható-e az SFD érték a burgonyagumó különböző minőségi jellemzőinek leírására, használható-e a Spektrális Fraktál Dimenziós (SFD) érték a burgonyagumók kiválasztott tulajdonságai alapján az egyes fajták elkülönítésére, s ha igen, mely állapotok határozzák meg ezt az elkülönítést.

A fenti céloknak megfelelően egy kiértékelő számítógépes program készült, amely meghatározza a burgonya gumók 4 állapotának – héjszín, nyers hússzín, főtt hússzín, 24 órás nyers gumóhús szürkülés – SFD értékeit az RGB szintérben, s annak minden alterében (R, G, B). Mindösszesen 13 fajta 4 vizsgálati periódusban készített 2080 db. képének analízisét végeztük el.

Az eredmények alapján általánosságként kijelenthetjük, hogy az SFD érték analízise csak abban az esetben használható a burgonyanemesítésben, ha a digitális felvételek egy bizonyos jól meghatározott, standard körülmények között lettek elkészítve.

A statisztikai elemzések (hipotézis vizsgálatok, főkomponens analízis és non-hierarchikus klaszter analízis) eredményeként megállapítottuk, hogy a vizsgált gumó jellemzők fajtán belüli minősítésére az SFD nem alkalmas.

Az azonos fajták különböző évek közötti eltérésének vizsgálatakor megállapítható volt, hogy az esetek nagy részében az azonos fajtán belül is szignifikáns különbségek vannak. Azt a következtetést vonhattuk le, hogy a fajták azonosítását nem egy meghatározott SFD értékhez, hanem az adott év ismert SFD értékű kontrolljához kell viszonyítani.

Az egyes fajták közötti eltérések évenkénti értékelésekor megállapítható, hogy függetlenül a tulajdonságtól vagy a vizsgált színtértől nincs olyan eset, melyben a fajta elkülönítés teljes egészében szignifikánsan megvalósulna. Minden évben van azonban olyan fajta, amely 100%-san elkülöníthető, de a fajták és tulajdonságaik évente változtak. Ugyanakkor az sem jelenthető ki, hogy a különböző tulajdonságok és a színterek eredményeinek variációjával az elkülönítés nem lehetséges.

Ennek a problémának megoldására alkalmaztuk a nem-hierarchikus klaszteranalízist. A módszer eredményeként a fajták elkülönítése minden évben megtörtént és a 4 tulajdonság együttes RGB SFD értéke és egy másik szintér adatainak összevetésével az elkülönítés teljes lesz.

Ennél fogva kijelenthetjük, hogy a célul kitűzött feladat megvalósítható, a bemutatott eredmények sikerrel hasznosíthatók a burgonyanemesítésben, de a gyakorlati alkalmazhatóságot még tovább kell vizsgálni.

Kulcsszavak: digitális képanalízis, fraktál, spektrális fraktál dimenzió, burgonyanemesítés, fajtaazonosítás, klaszteranalízis, nem-hierarchikus, klaszteranalízis

INTRODUCTION

Within the European project (IKTA-00101/2003, Berke *et al*., 2006) we proposed a uniform qualifying and classifying system (EMOR/EQCS - Exact Qualification and Classifying System) [1] for classifying potato genotypes. Analysis of digital images – determining Spectral Fractal Dimension (SFD) – was used to describe different characteristics of potato tubers.

Results from this study encouraged further research into the applicability of SFD values in potato breeding activities. Fractal analysis – as a method for image analysis – is only rarely used for separation and classification of biological systems [4] [5] [6], even though it is obvious that these systems possess fractal features. Berke *et al.* (2006) [1] used SFD for evaluation of biological objects [7, 8] including analysis of processing quality of potato tubers.

In currently used evaluation procedures of potato genotypes, culinary qualities are determined visually, with somewhat subjective kitchen–technology tests. It requires many years' experience and professional knowledge and at the same time, - because of its subjectivity – it gives no objective values. Specialists classify the samples simultaneously at the same time and quality is determined by taking their average value. Therefore a qualifying method based on objective values that will be able to separate potato varieties or to identify their quality, differences within genotypes in a relatively easy and economical way by using fractal features, is needed.

During the study, we were using a new approach to develop and verify the elements of qualifying method to reach a standardized procedure.

The aims of examinations:

1. To determine whether SFD value can be used to describe different characteristics of potato tubers,

2. to determine whether SFD value can be used to distinguish potato varieties based on the chosen tuber characters,

3. to determine which characteristics are the most decisive to make this separation.

Several methods have been worked out to determine fractal dimension (Fractional Brownian motion method, Fourier power spectrum, Relative Differential Box-Counting method (RDBC), Morphological method, Mass fractal, Spectral dimension method) [6].

The RDBC procedure was used by Berke [1]. He was trying to classify potato genotypes determining the SFD values of the studied parameters. However, he did not examine the parameters influencing or potentially influencing SFD values. In 2007 in his publication Hegedűs [3] gives a detailed analysis of the parameters influencing SFD values of images taken in RGB spectrum.

He concluded about the function (1) that:

> *"The function relates values to any image as specified in the definition and does not presuppose whether the spectrum of image (P) has any fractal features. The possible fractal features do not appear from the function-value either, because it represents the arithmetic mean of fractal dimensions gained through refinement in 8 steps, which was given triplet multiplier because of the triplet colour decomposition function. It is true, however, that it provides values proportionate with fractal dimensions with P having fractal structure; otherwise it yields an index typical of saturation."*

He states concerning values influencing the value of function that:

> *"Based on the results it was found that there is no universal SFD measuring – that is the measuring process should be adjusted to certain types of objects and it must contain concrete environmental and methodological data besides arithmetical algorithms. Naturally, error-limits should be given for all definitions."*

To back up above results, a study was conducted and results [2] confirmed statements of Hegedűs. The study was finalised with the proposal of a standardized methodology for taking images.

Material and methods

Sampling

Samples were received from the kitchen-technology test of the Potato Research Centre of the Pannon University. They were prepared according to standard methodology of Central Agricultural Office used for national evaluation of variety candidates. In total 11 varieties from Keszthely and 2 controls from the Netherlands were studied (Rioja, White Lady, Gólát, Kánkán, Hópehely, Luca XL, Lorett, Balatoni rózsa, Démon, Vénusz Gold, Katica and Desirée, Cleopatra) during 4 periods. Four characters were studied in 10 repetitions. Altogether 2080 samples were analysed. Table 1 gives a summary of the genotypes and examined characters.

Taking images

Images were taken under standardized conditions: Canon EOS 30D type digital camera was used to take 24 bit colour (RGB) rasterize images, with a lens of Canon 18-55 mm having a definition of 2544x1696 pixels, 72 dpi, fix local distance, perpendicular projection and an artificial light-source of constant intensity (Sigma EM-140 DG circular flash) was used, in visible spectrum and in JPG format. Having glimmer-free surface in the case of raw flesh-colour, blotting of fresh surface was necessary. The images taken went through pre-processing which made the background of the given object homogenous (white or black background colour), thus ensuring the determination of the SFD values of the object.

Software

To analyze the images, we developed a computer program using MatLab (7.0.0.19920-R14) developing system, which used the “box-counting method” to determine SFD value:

$$\frac{d}{k}\sum_{i=1}^{k}\frac{\ln n_i}{\ln m_i} \qquad (1)$$

Where:

d: layer (dimension=3), k: number of iteration = 8,

n: number of not empty cubes, m: the total of cubes.

This function has been modified from G. Hegedűs [3], describing image spectrum.

The algorithm determines the fractal features of the image colour depth for the RGB, R, G and B colour spectrum. The values measured (RGB->TFV[1]; R->RFV[2]; G->GFV[3]; B->BFV[4]) were stored in the MS Excel tables (52 workbooks (basic-table)= 4 season x 13 variety).

Statistical analysis

For statistical processing of data, three kinds of methods were used:

1. Classical statistical measuring numbers: average, scattering, minimum, maximum, absolute deviation, relative deviation,

2. Hypothesis studies: using t-test (Student-test), Two-way variant analysis (ANOVA / F-test)

3. Non-hierarchic cluster analysis: global optimalization procedure, coefficient of Similarity ratio, with the help of SynTax statistical program. To make description easier, we used the Eigen analysis - Scatter-diagram.

Function of "Similarity ratio":

$$1-\frac{\sum_i x_{ij}\ x_{ik}}{(\sum_i x_{ij}^2+\sum_i x_{ik}^2-\sum_{ij} x_i x_{ik})} \qquad (2)$$

1 TFV=Total Fractal Value
2 RFV=Red Fractal Value
3 GFV=Green Fractal Value
4 BFV=Blue Fractal Value

Results and discussion

In 1984 Pentland [4] found that the intensity of surfaces possess real fractal features. He proved that fractal functions can be used effectively for the characterisation of three dimensional surfaces. Quevedo et al. [5] characterised surfaces fractal features of different foods, like vegetables, fruits and starch granules embedded in gelatine. For evaluation of the fractal structure of scrammed bread Gonzales [6] determined FD values using several methods. He stated that the method of “Box-counting” method (RDBC) is better for the characterisation of granules of scrammed bread than using the grade of homogeneity of granules.

Analysis of variance results suggested that varieties can be distinguished based on the SFD value of examined tuber characters (except boiled flesh colour and raw flesh colour). The value of distinction is variable, being the highest in the case of sum of the four studied characters (RERFBFSF). However the sum of the three values (RERFSF, RERFBF) provides also a very good distinction value. In most cases there is an interaction between varieties and characters.

Based on the t-test following categories were defined to be practically used in the agricultural studies.

P >0.15	not significant
P 0.15>X>0.05	slightly significant
P 0.05>X>0.01	averagely significant
P 0.01>X>0.001	medium significant
P 0.001>X>0.0001	strongly significant
P <0.0001	very strongly significant

Qualification within variety

SFD values were determined for the total (T), R, G and B colour spectrums. For each chosen character data show very close values for T, R, G and B spectrum.

Based on the relative deviations of minimum and maximum values of examined schemes it became evident that these values are much higher than the relative deviation of the lowest significant value. The same holds true for the yearly deviations within varieties.

SFD value of varieties

Deviations between years between and within varieties were studied, for every trait and spectrum. Simultaneously, we analyzed the summarized effects of traits to find out the decisive elements for different traits belonging to the total value.

In Table 2, the numerator contains the number of significant cases, while the denominator the total case-number. There were only 4 cases out of the possible 78 when there was no significant deviation between the years.

So we could state that in the majority of cases, there were significant differences between identical varieties. We concluded that the identification of varieties should be related not to one particular SFD value but rather to the known SFD value of the given year. At the same time, this fact indicates that conditions of the growing season (meteorological deviations to differences in soil parameters) have an effect on the selected traits to be examined and – through this – on SFD values.

Yearly examination of genotypes

We evaluated the differences between varieties for each experimental year. From Table 3, it can be stated that irrespective of characteristic traits or the spectrum studied, there is not a single case where separation of varieties could be significantly realized in full. There are, however, varieties every year, which can be fully – 100% - separated, but varieties and their traits changed every year. At the same time, it cannot be stated either, that separation with the variation of the results of their different traits and spectrums is not possible. It was theoretically expected that varieties will create groups, since they are close relatives (e.g. Luca XL and Lorett have same parents).

Cluster analysis

We used the non-hierarchical cluster procedure, the global optimalization method and similarity ratio coefficient for the analysis. From the Tables 4-7 it can be stated that the separation of varieties was performed every year and by combining total value (TVF) and the values of another spectrum, separation will be complete.

The graphical presentations of the above analysis – Scatter-diagrams – for certain seasons are illustrated in Figure 1-5. The Scatter-diagrams well-indicate that the varieties are distinguishable. When we compare them with the results of significance tests, it can be stated that cluster analysis separates varieties even when significance study does not. It can be detected on the diagrams through the fact that given varieties take up identical x- or y-value.

SUMMARY

We studied the potentials of Spectral Fractal Dimension (SFD) – as an image analysis procedure – for potato breeding research. Based on the results of studies performed under standardized conditions and based on different statistical analysis the method is not applicable for the characterisation of quality differences within genotypes. However we can conclude that SFD value is suitable for the separation of potato varieties, but it can only be realized when it is related to the control sample from the same year or season.

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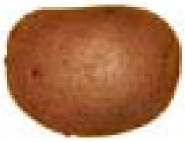
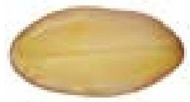
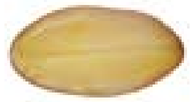
Table 1: Summary of the examined varieties and tuber characters.
1. Táblázat: A vizsgált fajták és gumójellemzők

Variety	Skin colour (RE)	Row flesh colour (RF)	Boiled flesh colour (BF)	Row flesh colour after 24 hour (SF)
Balatoni rózsa				
Cleopatra[1]				
Desirée[2]				
Démon				
Góliát				
Hópehely				
Katica				

-4.Duch variety

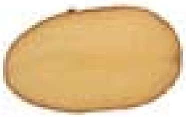
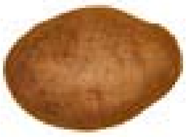
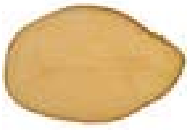
Variety	Skin colour (RE)	Row flesh colour (RF)	Boiled flesh colour (BF)	Row flesh colour after 24 hour (SF)
Kánkán				
Lorett				
Luca XL				
Rioja				
Vénusz Gold				
White Lady				

Table 2: Demonstration the separability of varieties. The numerator contains the number of significant cases, while the denominator the total case-number.

2. Táblázat: A fajták elkülöníthetőségének illusztrálása.. Az értékeknél a számláló a szignifikáns esetek számát, a nevező az összes esetszámot tartalmazza

Variety	TFV RE	BFV RF&BF	TFV RE&RF&SF	BFV RF&BF&SF	BFV RE&RF&SF	TFV RE&RF&BF&SF
Balatoni rózsa	4/6	2/3	5/6	2/3	5/6	3/3
Démon	5/6	2/3	5/6	2/3	4/6	2/3
Katica	2/4	1/1	2/3	1/1	2/3	1/1
Luca	5/6	3/3	3/6	1/3	3/6	3/3
White Lady	5/6	3/3	3/6	3/3	3/6	3/3
Cleopatra	3/3	1/1	2/3	1/1	3/3	1/1
Góliát	5/6	1/3	4/6	0/3	4/6	3/3
Kánkán	6/6	0/3	6/6	2/3	3/6	3/3
Rioja	5/6	2/3	2/6	0/3	2/6	2/3?
Desirée	5/6	0/3	5/6	2/3	5/6	2/3
Hópehely	5/6	2/3	6/6	2/3	4/6	3/3
Lorett	3/6	2/3	6/6	2/3	3/6	3/3
Vénusz	5/6	2/3	6/6	2/3	3/6	3/3

Table 3: Separation results of varieties in the four examination periods based on the spectrum studied and on the tuber characters.

3. Táblázat: A fajták elkülönítésének eredményei a négy vizsgálati időszakban a spektrumok és gumótulajdonságok viszonylatában.

Spectrum& Sample	200711	200802	200811	200902
TFV	50.6% Kánkán=100%	74.4% Cleopatra=100%	58.4% Katica=100%	48.5% Vénusz=100%
RFV	41.6% Kánkán=100%	56.4% Balatoni rózsa=100%	57.1% Katica=100%	13.6%
GFV	41.6% Kánkán=100%	49.4%	42.9%	18.2 %
BFV	51.9% Kánkán=100% Katica=100%	31.2%	57.1% Kánkán=100%	51.5 %
TFVRE	59,0%	56,4%	43,6%	56,1%
RFVRE	40.3% Balatoni rózsa=100% Lorett=100%	33.8%	29.5%	28.8%

Spectrum& Sample	200711	200802	200811	200902
GFVRE	10.4%	11.7%	26.9% Whyte Lady=100%	16.7%
BFVRE	57.1%	38.5%	20.5%	43.9%
TFVRF	49.2% Góliát=100%	59.7%	56.1%	22.7%
RFVRF	43.1%	64.1%	43.1%	18.2%
GFVRF	37.9%	21.8%	33.8%	22.79%
BFVRF	27.7%	53.2%	32.3%	57.6% Whyte Lady=100%
TFVBF		57.7%	56.4%	20.0% Vénusz=100%
RFVBF		69.2%	29.9%	34.8%
GFVBF		11.7%	20.8%	21.2%
BFVBF		55.1%	44.2%	39.4%
TFVSF	53.8%	37.2%	53.8%	27.3%
RFVSF	44.2% Balatoni rózsa=100%, Desiree=100%	44.9%	40.3% Cleopatra=100%	24.2% Vénusz=100%
GFVSF	2.6%	18.2%	22.1% Cleopatra=100%	31.8% Vénusz=100%
BFVSF	71.4%	47.4% Balatoni Rózsa=100%	50.6%	33.3%
TFVRF&SF	29.2%	52.6% Desirée=100%	59.1% Katica=100%	24.2%
RFVRF&SF	18.2%	55.1% Balatoni Rózsa=100%, Desirée=100%	42.4%	0.0%
GFVRF&SF	24.2%	46.8% Desirée=100%	40.9%	31.8% Balatoni Rózsa=100%,
BFVRF&SF	31.8%	59.7%	38.2% Katica=100%	47.0%
TFVRF&BF		65.4%	50.0% Katica=100%	30.3% Vénusz=100%

Spectrum& Sample	200711	200802	200811	200902
RFVRF&BF		65.4% Balatoni Rózsa=100%, Cleopatra=100%	42.4% Katica=100%	1.5%
GFVRF&BF		37.2% Balatoni róz-sa=100%	30.3% Katica=100%	15.2%
BFVRF&BF		66.7%	14.5%	57.6%
TFVRF&RE	51.3% Kánkán=100%	45.5%	54.5% Katica=100%	53.0%
RFVRF&RE	25.8%	35.9% Balatoni róz-sa=100%	50.0% Katica=100%	21.2%
GFVRF&RE	25.8%	27.3%	40.9% Katica=100%	12.1%
BFVRF&RE	36.4%	50.6%	25.5%	51.5%
TFVRE&SF	47.4% Kánkán=100%	50.6%	25.5%	50.0%
RFVRE&SF	23.1%	55.1% Balatoni róz-sa=100%	27.3%	30.3%
GFVRE&SF	5.2%	45.5%	24.2%	16.7%
BFVRE&SF	60.3%	49.4%	42.4%	33.3%
TFVRE&BF		36.4%	48.5% Katica=100%	54.5% Vénusz=100%
RFVRE&BF		43.6% Balatoni róz-sa=100%	27.3%	19.7%
GFVRE&BF		23.4%	27.3%	10.6%
BFVRE&BF		41.6%	31.8%	40.9%
TFVBF&SF		38.5% Cleopatra=100%	68.2%	25.8%
RFVBF&SF		55.1% Balatoni róz-sa=100% Desirée=100%	43.9% Kánkán=100%	34.8%
GFVBF&SF		41.6% Desirée=100%	37.9%	27.3% Vénusz=100%
BFVBF&SF		54.5%	60.6% Kánkán=100%	45.5%

Spectrum& Sample	200711	200802	200811	200902
TFVRE&RF&BF		50.6%	47.0% Katica=100%	50.0% Vénusz=100%
RFVRE&RF&BF		46.2% Balatoni rózsa=100%	43.9%	12.1%
GFVRE&RF&BF		29.5% Balatoni rózsa=100%	24.2%	10.6%
BFVRE&RF&BF		53.2%	22.7%	48.5%
TFVRE&BF&SF		53.8% Desirée=100%	68.2%	45.5% Vénusz=100%
RFVRE&BF&SF		57.7% Balatoni rózsa=100%	40.9%	27.3%
GFVRE&BF&SF		49.4%	47.0%	19.7%
BFVRE&BF&SF		49.4%	59.1% Kánkán=100%	42.4%
TFVRE&RF&SF	46.2% Kánkán=100%	62.8%	54.5% Katica=100%	48.5% Vénusz=100%
RFVRE&RF&SF	29.5% Balatoni rózsa=100%, Kánkán=100%	53.8% Balatoni rózsa=100%	45.5% Katica=100%	19.7%
GFVRE&RF&SF	37.7% Kánkán=100%	50.6%	33.3% Katica=100%	15.2%
BFVRE&RF&SF	52.6% Kánkán=100%	62.3%	39.4% Katica=100%	53.0%
TFVRF&BF&SF		50.0%	66.7% Katica=100%	31.8% Vénusz=100%
RFVRF&BF&SF		56.4% Balatoni rózsa=100% Desirée=100%	45.5% Katica=100%	0.0%
GFVRF&BF&SF		44.2%	39.4% Katica=100%	22.7%
BFVRF&BF&SF		58.4%	59.1%	59.1%

Table 4
Cluster 200711-i season

	SIMILARITY RATIO			
	TFV	RFV	GFV	BFV
BRCV[3]	0,0695	0,0342	0,0220	0,0303
CLUSTER 1	Balatoni	Balatoni	Balatoni	Balatoni
CLUSTER 2	**Cleopatra Desirée**	Cleopatra	Cleopatra	**Cleopatra Desirée**
CLUSTER 3	Démon	Desirée	Desirée	Démon
CLUSTER 4	Góliát	Démon	Démon	Góliát
CLUSTER 5	Hópehely	Góliát	Góliát	Hópehely
CLUSTER 6	Katica	**Hópehely VénuszGold**	**Hópehely LucaXL**	Katica
CLUSTER 7	Kánkán	Katica	Katica	Kánkán
CLUSTER 8	Lorett	Kánkán	Kánkán	Lorett
CLUSTER 9	LucaXL	Lorett	Lorett	LucaXL
CLUSTER 10	Rioja	LucaXL	Rioja	Rioja
CLUSTER 11	Vénusz Gold	Rioja	Vénusz Gold	Vénusz Gold
CLUSTER 12	White Lady	White Lady	White Lady	White Lady

Table 5
Cluster 200802-i season

	SIMILARITY RATIO			
	TFV	RFV	GFV	BFV
BRCV	0,0733	0,0441	0,0188	0,0387
CLUSTER 1	**Balatoni rózsa Góliát**	Balatoni	Balatoni	**Balatoni rózsa Góliát**
CLUSTER 2	Cleopatra	Cleopátra	**Cleopatra Hópehely**	Cleopatra
CLUSTER 3	Démon	Démon	Démon	Démon
CLUSTER 4	Desirée	Desirée	Desirée	Desirée
CLUSTER 5	Hópehely	Góliát	Góliát	Hópehely
CLUSTER 6	Kánkán	**Hópehely Kánkán**	Kánkán	Kánkán
CLUSTER 7	Luca XL	Luca XL	Luca XL	Luca XL
CLUSTER 8	Rioja	Rioja	Rioja	Rioja
CLUSTER 9	Lorett	Lorett	Lorett	Lorett
CLUSTER 10	Vénusz Gold	Vénusz Gold	Vénusz Gold	Vénusz Gold
CLUSTER 11	White Lady	White Lady	White Lady	White Lady

Table 6

Cluster 200811-i season

	SIMILARITY RATIO			
	TFV	RFV	GFV	BFV
BRCV	0,0001	0,0014	0,0003	0,0001
CLUSTER 1	Balatoni rózsa	Balatoni rózsa	Balatoni rózsa	**Balatoni rózsa Góliát**
CLUSTER 2	Cleopatra	Cleopatra	Cleopatra	Cleopatra
CLUSTER 3	**Desirée Démon**	Desirée	**Desirée Kánkán**	Desirée
CLUSTER 4	Góliát	Démon	Démon	Démon
CLUSTER 5	Hópehely	Góliát	Góliát	Hópehely
CLUSTER 6	Kánkán	Hópehely	Hópehely	Katica
CLUSTER 7	Katica	Katica	Katica	Kánkán
CLUSTER 8	Lorett	**Kánkán Rioja**	Lorett	Lorett
CLUSTER 9	Luca XL	Lorett	Luca XL	Luca XL
CLUSTER 10	Rioja	Luca XL	Rioja	Rioja
CLUSTER 11	Vénusz Gold	Vénusz Gold	Vénusz Gold	Vénusz Gold
CLUSTER 12	White Lady	White Lady	White Lady	White Lady

Table 7

Cluster 200902-i season

	SIMILARITY RATIO			
	TFV	RFV	GFV	BFV
BRCV	0.03	0.03605	0.01025	0.01288
CLUSTER 1	Balatoni rózsa	Balatoni rózsa	Balatoni	**Balatoni rózsa Démon**
CLUSTER 2	**Démon Katica**	Démon	**Démon Katica**	Desirée
CLUSTER 3	Desirée	Desirée	Desirée	Góliát
CLUSTER 4	Góliát	Góliát	Góliát	Hópehely
CLUSTER 5	Hópehely	Hópehely	Hópehely	Kánkán
CLUSTER 6	Kánkán	Kánkán	Kánkán	Katica
CLUSTER 7	Lorett	Katica	Lorett	Lorett
CLUSTER 8	Luca XL	Lorett	Luca XL	Luca XL
CLUSTER 9	Rioja	**Luca XL Rioja**	Rioja	Rioja
CLUSTER 10	Vénusz Gold	Vénusz Gold	Vénusz Gold	Vénusz Gold
CLUSTER 11	White Lady	White Lady	White Lady	White Lady

4-7 Tables: Separation of varieties based on all the examined characters of the total spectrum, and its sub spectrums (RFV, GFV, BFV).

4-7 Táblázat: Az egyes fajták elkülönülése valamennyi vizsgált tulajdonság figyelembevételével a teljes spektrumra (TFV), és annak altereire (**RFV, GFV, BFV**).

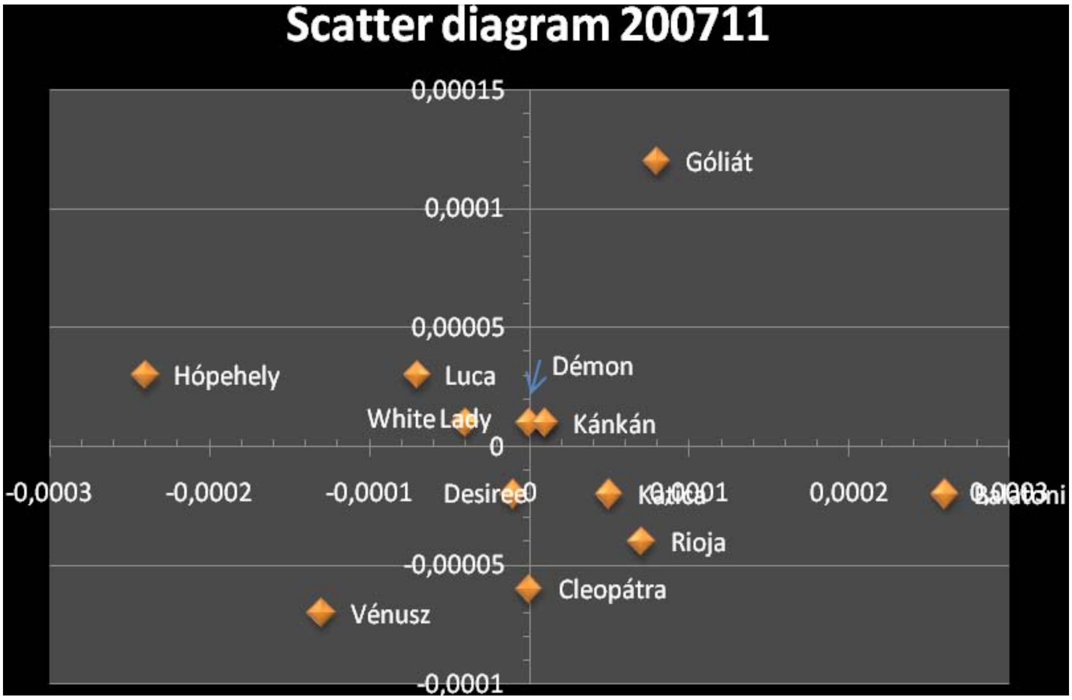


Figure 1: SFD values of four characters for 12 varieties (2007 autumn)
1. Ábra: A 4 tulajdonság SFD értékeinek szóródási diagramja 12 fajtára (2007 őszi időszak)

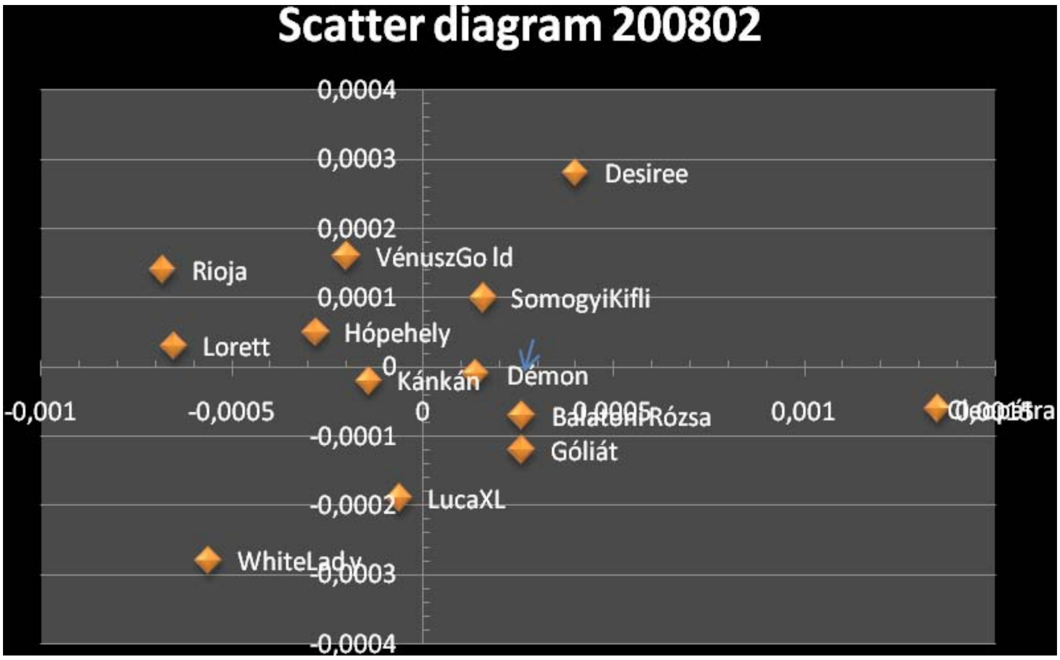


Figure 2: SFD values of four characters for 12 varieties (2008 spring)
2. Ábra: A 4 tulajdonság SFD értékeinek szóródási diagramja 12 fajtára (2008 tavaszi időszak)

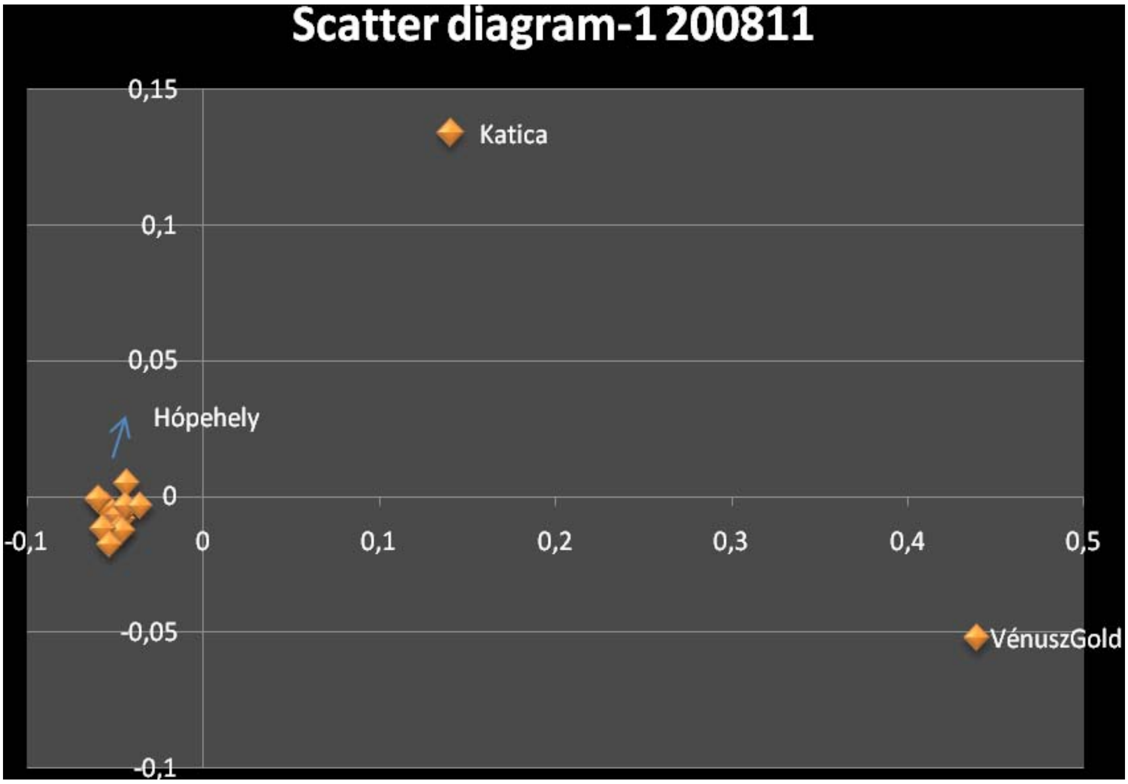


Figure 3: SFD values of four characters for 13 varieties (2008 autumn)
3. Ábra: A 4 tulajdonság SFD értékeinek szóródási diagramja 13 fajtára (2008 őszi időszak)

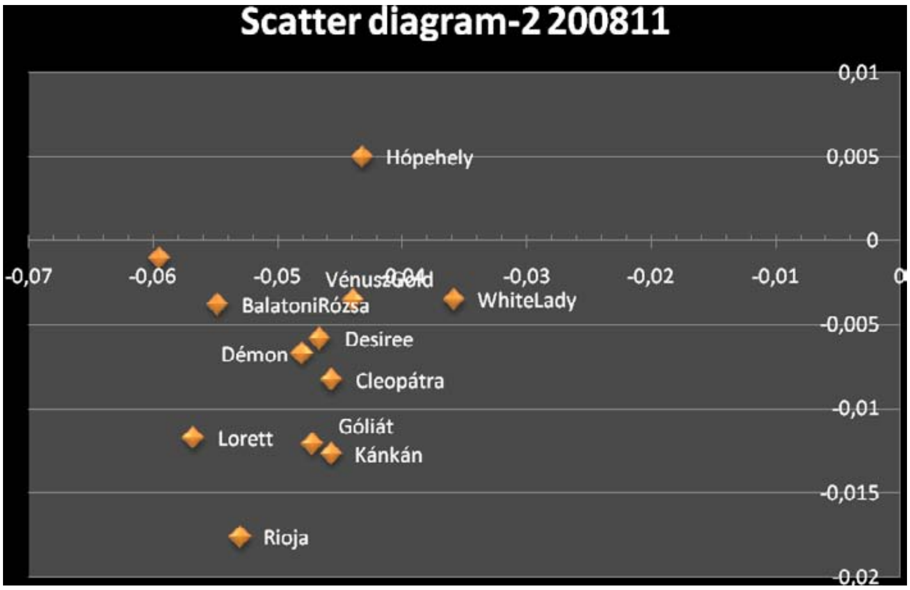


Figure 4: SFD values of four characters for 12 varieties (2007 autumn, without Katica)
4. Ábra: A 4 tulajdonság SFD értékeinek szóródási diagramja 12 fajtára (Katica fajta nélkül, 2008 őszi időszak

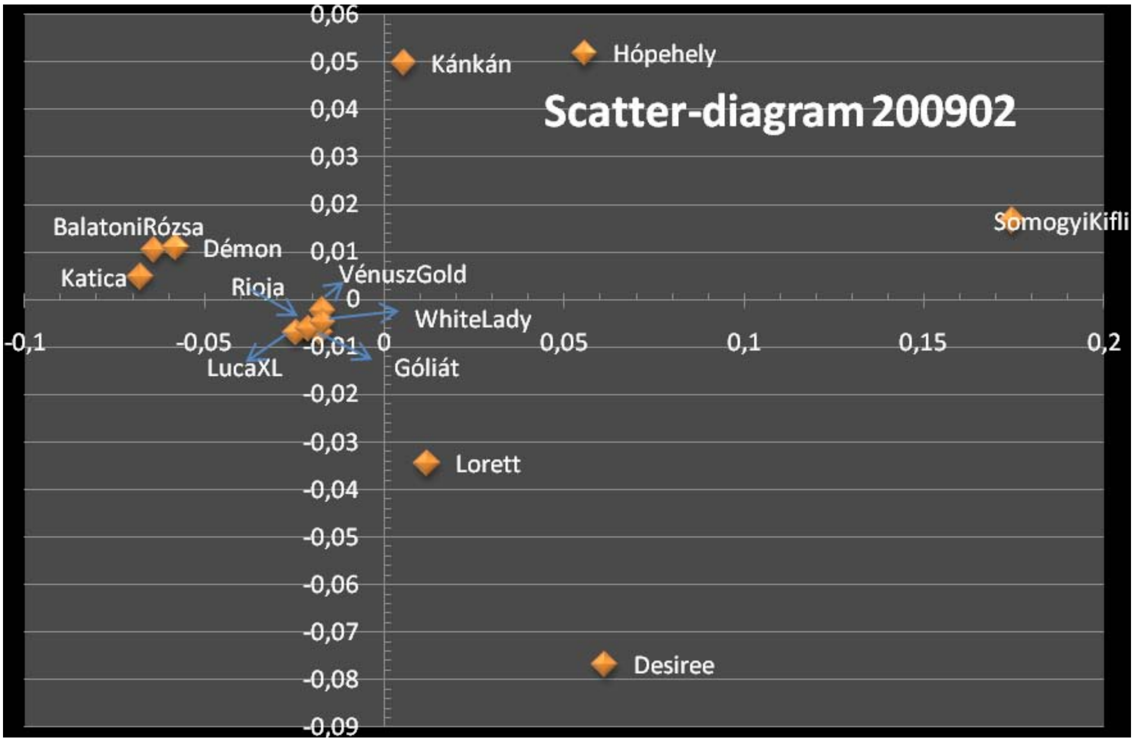


Figure 5: SFD values of four characters for 12 varieties (2009 spring)
5. Ábra: A 4 tulajdonság SFD értékeinek szóródási diagramja 12 fajtára (2009 tavaszi időszak)

1 -4 Duch variety
2
3 BCRV= Best Result Criteria Value