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NS PEPPER VARIETIES IN A MULTIVARIATE FRUIT ANALYSIS

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Abstract

Peppers (*Capsicum annuum* L.) have a very diverse use in Balkan cuisines and Serbia is no exception. Different ways of consumption has come as a result of various types, colours and sizes of peppers. The aim of this study was the phenotypic evaluation of 16 pepper varieties. Ten pepper varieties were selected at the Institute of Field and Vegetable Crops in Novi Sad (IFVCNS), and 6 were domesticated pepper varieties from the IFVCNS assortment. The trial was conducted in field conditions on chernozem soil in 2016. The experiment was established in a randomized block design with three replications. Five fruits per replicate were used for a phenotypic evaluation. The varieties were characterized for 7 quantitative and 5 qualitative fruit traits. The principal component analysis (PCA) was used to identify the most significant traits and to show distances between the varieties in a biplot. The cluster analysis was applied to show similarities between the varieties and to create common groups. In the PCA biplot all pepper varieties were grouped into five groups, but in the cluster analysis they made six groups. The biggest group in both analyses consisted of bell peppers. Those multivariate analyses are suitable to represent differences and similarities among pepper varieties visually.

Key words: *Capsicum annuum, Cluster, Fruit evaluation, PCA, Serbia.*

Introduction

In most cultivated species, the loss of genetic variability began with the process of domestication (Tang et al. 2010). In contrast, thousands of years of human selection in different conditions and growing methods bring to the development of new mutations and gene combinations that are of agricultural importance, with low probability to occur under the pressure of natural selection. Pepper (*C. annuum* L.) is one of the major vegetable species in Serbia. Pepper comparing to other vegetable crops (excluding potato) has the first rank in Serbia with 16,977 ha in 2016 (Statistical Office of the Republic of Serbia, 2017). In different regions of Serbia people consume pepper fruits with various shapes, sizes and colors (Danojevic *et al*., 2016). Fruit characterization is the first step in the description and classification of pepper germplasm for breeding purpose. The application of appropriate statistical methods is a useful tool for the description and genotype classification, since it enables plant breeders to identify and select valuable genetic resources in a breeding programs (Jankulovska *et al*., 2014). Smith and Basavaraja (2005) and Bharadwaj *et al*., (2007) found that during selection of peppers a very important traits are: fruit weight, fruit length and fruit diameter because they directly affecting the yield. Significant positive correlation between the morphological traits and AFLP markers indicated that the difference in AFLP distances tend to reflect the morphological differences. Therefore, the genotypes can easily be distinguished using only phenotypic traits (Geleta *et al*., 2005). Hierarchical cluster analysis is a useful tool for partitioning variability of collections for managing them effectively and provides ground for curators and breeders to enhance the usefulness of their collections (Peeters and Martinelli, 1989). Many scientists around the world have studied variability in pepper

germplasm and have clustered them into genetically related groups in order to select superior genotypes for use in future breeding programs (Cvikić, 2009; Occhiuto *et al*., 2014, Silva *et al*., 2015). The aim of this research was to characterize pepper varieties for main fruit traits visually and to found relationship between traits and varieties.

Materials and Methods

Sixteen pepper genotypes from the Institute of Field and Vegetable Crops assortment were sown in the last week of March in 2016 in a plastic house. The field trial was conducted at the experimental field of the Institute of Field and Vegetable Crops (Rimski Šančevi), Novi Sad (Serbia). Genotypes were transplanted in tree replicates (rows) with 20 plants in each row at last decade of May. Density of plants was 70 x 25 cm. Regular cultural practices were applied throughout the growing season (inter-row cultivation, irrigation). Five fruits per replicates were harvested in October at the physiological maturity. The following quantitative traits were analyzed: fruit weight, fruit length, fruit diameter, fruit index, locule number, number of apexes, and pericarp thickness. Also fruit color before maturity, fruit color at maturity, fruit shape in longitudinal section, fruit attitude and presence of capsaicin in placenta were noted according to UPOV Test Guidelines (2006). Software package Statistica for Windows ver. 12, (StatSoft. Inc. 2013) were used for Principal Component Analysis (PCA) and Cluster Analysis (CA) to evaluate the level of diversity for pepper varieties and to rank the contribution of the variables. Mean values per genotype were standardized (Mean=0, SD=1) and used for analysis. For the construction of dendrogram Complete Linkage with squared Euclidean dinstances was used. Principal components have been extracted until the Eigen value > 1.

Results and Discussion

PCA indicated that the first three components explained 84.81% of the total variance (Table 1). Since the first three principal components (PC) were over Eigenvalue 1, only those were intepreted.

Table 1. Eigenvalues and total variance of the first three principal components (PC) in pepper varieties.

PC	Eigenvalue	% Total variance	Cumulative Eigenvalue	Cumulative variance %
1	6.205197	51.70998	6.20520	51.7100
2	2.834814	23.62345	9.04001	75.3334
3	1.138196	9.48497	10.17821	84.8184

The most important positive traits in first PC were: fruit index, fruit shape in longitudinal section, and capsaicin in placenta, while the negative were: fruit diameter, fruit weight, pericarp thickness and number of apexes (Table 2).

Table 2. Correlation between original variables and the first three principal components (PC) in pepper varieties.

Variable	PC 1	PC 2	PC 3
Fruit Length	0.103355	**-0.938267**	-0.076459
Fruit Diameter	**-0.953260**	-0.203104	0.144728
Fruit Index	**0.948926**	0.134171	-0.120185
Fruit Weight	**-0.848412**	-0.240125	0.161494
Number of Apexes	**-0.810313**	0.502003	-0.134416
Locule Number	-0.567144	0.531240	-0.381190
Pericarp Thickness	**-0.936573**	-0.175492	0.076035
Fruit Color before Maturity	0.324726	0.257422	**0.877431**
Fruit Color at Maturity	-0.642038	-0.440472	-0.020056
Fruit Shape in Longitudinal Section	**0.772349**	-0.535953	0.102178
Fruit Attitude	0.021784	**-0.823186**	-0.213464
Capsaicin in Placenta	**0.833944**	0.217655	-0.274644

Ilić *et al*., (2013), found that beside the fruit yield per plant, fruit weight and pericarp thickness were the most important variables in the first PC. In the second PC the most important traits were: fruit length and fruit attitude. Bozokalfa *et al*., (2009) found that in the first two PC, the greatest variation was described with following fruit traits: fruit diameter, fruit weight, fruit volume, fruit wall thickness, pedicel length and fruit length. Based on PCA analysis, pepper varieties have been grouped according to the fruit characteristics (Figure 1).

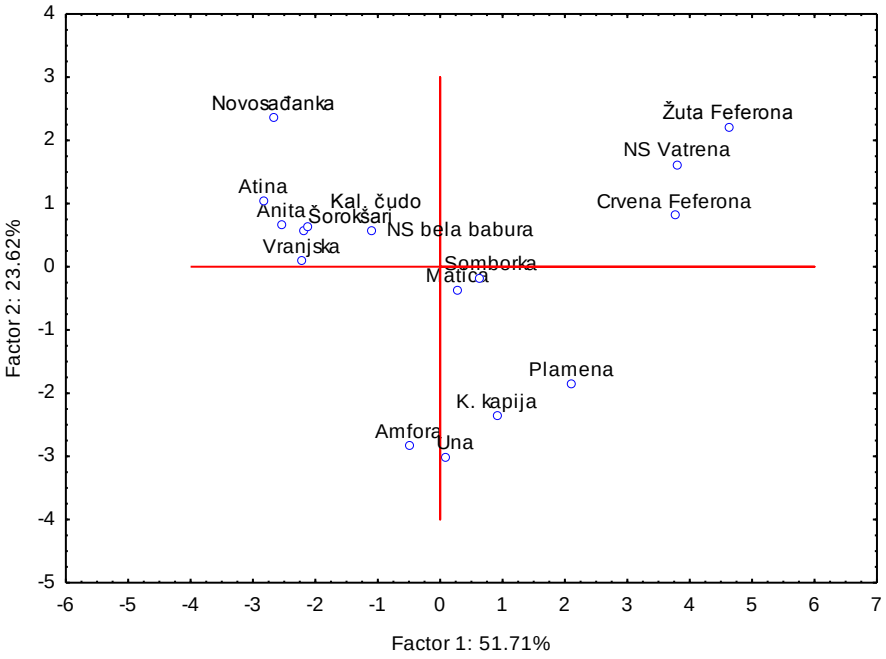

Figure 1. Biplot of the two principal components for the NS pepper varieties based on fruit traits

In the first quadrant were varieties: Crvena feferona, Žuta feferona and the new NS Vatrena. All varieties belonged to small hot peperoni type with erect fruit, while the largest differences were at color maturity. Bell peppers and Novosađanka (tomato shaped pepper) were

represented in the second quadrant. In the lower part of biplot were kapia type varieties (Amfora, Una, and Kurtovska kapia), as well as shipka type (Plamena). Varieties with upright fruit position and conical shape (Matica and Somborka) were located in the center of biplot. Although that relatively small number of varieties were included in this analysis, they showed high variability. Because of high diversity for morphological fruit traits in Capsicum, this genus is highly applicable for genetics and breeding in practical classes with students (Prohens *et al*., 2010). All our varieties could be also presented through a picture of one or two fruits per genotype and grouped according to PCA analysis. That type of visual fruits presentation will be good for students to learn better fruit similarity and divergence between pepper genotypes. A great relationship were established with PCA analysis between the major fruit characteristics: fruit weight, pericarp thickness and fruit diameter (Figure 2). Fruit attitude is in the great dependence on the fruit length (shorter fruits are usually upright). The number of apexes is highly dependent on the locule number, and the pungency is related to the fruit index.

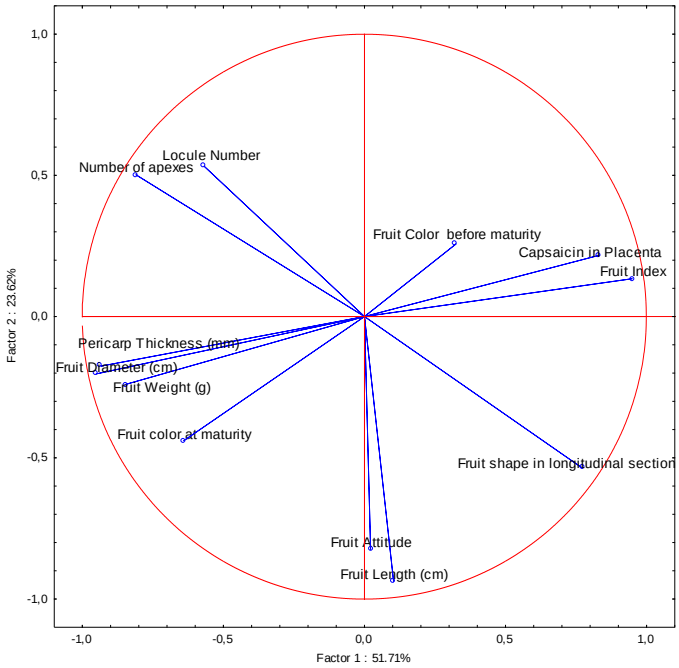

Figure 2. The two principal components for the NS pepper varieties based on fruit traits

Zečević (2001) noted that the fruit diameter, fruit length, pericarp thickness, number of fruits and fruit weight are in a strong correlation. Positive correlation was found between fruit weight and fruit length, fruit diameter, pericarp thickness, and locule number (Danojević *et al*., 2016). According to Cvikić (2009) the cluster analysis based on the quantitative traits gave results that are much more applicable than grouping of genotypes with morphological markers. Reason of this phenomenon is because the fruit weight has greater variability than any other quantitative trait, and it has the highest contribution in multivariate analysis. Although researchers usually evaluate the germplasm variability separately for quantitative and qualitative traits, a small number of them combines these two trait types in a one multivariate analysis. Based on cluster analysis, varieties included in this research have been grouped into 6 groups (A-F) (Figure 3). In group A (bell pepper type), were the most number of varieties: Vranjska, Anita, Šorokšari (Soroksari), Atina, Kalifornijsko čudo (Cal. Wonder) and Novosadska bela babura. Variety Vranjska is set aside in a separate subgroup primarily due to the hanging fruit position, while other varieties have upright position. Novosađanka is

allocated in a second group (B) as the only tomato variety in that group. Varieties with conical fruit shape and the upright position (Matica and Somborka) were in the group C. The varieties with kapia fruit type (Kurtovska kapija, Amfora, Una) and shipka type (Plamena) have been classified into group D and E. Žuta Feferona, Crvena Feferona and NS Vatrena (small hot peperoni type) were clustered in the group F.

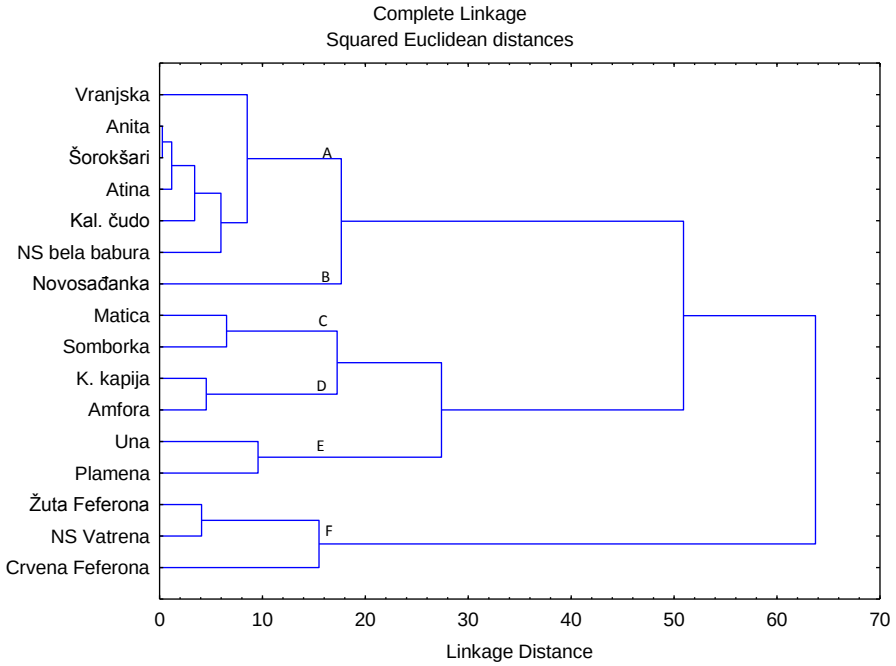

Figure 3. Dendrogram of NS pepper varieties based on evaluated fruit traits

Conclusions

Evaluated varieties showed significant differences from the Institute of Field and Vegetable Crops assortment. The largest group of varieties consisted of bell peppers but they showed very similar characteristics. Choosing of some important fruit traits and use of Principal Component Analysis and Cluster Analysis is appropriate method for good visual presentation of different pepper varieties. There is still a need for increasing the number of new pepper varieties, because customers want pepper fruits with different sizes, colors, shapes and pungency levels.

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