# Evaluation of fruit traits in pepper (type kapiya) collection from North Macedonia

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***Abstract***

**Fruit traits for 19 accessions of *Capsicum annuum* L. from North Macedonia were evaluated. The vernacular names indicated that these accessions belong to kapiya type or peppers intended for processing. The trial was conducted in 2018 in the Skopje area on open field in a randomized block design with three replications. Morphological characterization was conducted for several quantitative (length, diameter, weight, pericarp thickness) and qualitative (color, shape, shape at pedicel attachment and blossom end and cross-sectional corrugation) fruit traits. Average fruit weight ranged from 66.12 g (genotype FZNH 319) to 159.51 g (genotype FZNH 537), with average fruit length from 12.46 cm (genotype FZNH 528) to 18.12 cm (genotype FZNH 268). The fruit shape in some accessions was not typical for kapiya types, but all accessions had high average values for fruit wall thickness which is the preferred parameter for processing. The analysis revealed that there are significant statistical differences between the evaluated accessions. Hierarchical cluster analysis was performed and the genotypes were grouped into three clusters. The PCA (principal component analysis) identified 3 principal components explaining 74.63% of the total variability. The data obtained can be useful in identifying potential genotypes for further selection or recommendation for direct inclusion in production, since the majority of producers of this type of pepper prefer local or commercial cultivars instead of hybrids.**

**Keywords:** *Capsicum*, landraces, variability, principal component analysis (PCA), cluster analysis

## INTRODUCTION

Of all the species from the Capsicum genus, *Capsicum annuum* L. is the most widespread and economically important in the food industry (Bosland and Votava, 2012). Kapiya type peppers take a large portion of the total pepper production in the country and are leading vegetables used in the processing industry (Martinovska Stojcheska et al., 2019). Many farmers that are growing peppers for processing prefer local or commercial cultivars instead of hybrids. The majority of individual farmers in North Macedonia, as well as in the region, maintain and grow at least 3 to 4 local landraces of pepper for fresh or processed consumption (Ivanovska and Andonov, 2018; Todorova, 2007; Todorova and Djinovic, 2017). The Balkan countries have a long tradition in pepper production. Knupffer (2016) identified 2384 accessions of *Capsicum annuum* L. originating from the Balkan Peninsula that are preserved in the world gene banks. This wealth of pepper diversity in the region is widely utilized in the production and represents a significant source of income for the smallholder farmers.

The characterization of plant genetic resources is necessary to identify valuable accessions for breeding programs and to develop efficient conservation strategies not only in gene banks but also in situ (González-Pérez et al., 2014). Therefore, the use of standardized descriptors is an important practice for germplasm identification, characterization and comparison (Pereira Dias et al., 2020). Quantitative fruit characters – weight, length,

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diameter and pericarp thickness are of great importance in describing fruits and genotypes (Todorova, 2007). The presented study aims to evaluate the diversity of the collection based on morphological characterization of 19 local genotypes of kapiya peppers and to identify their potential as material for future breeding activities.

## MATERIALS AND METHODS

### Plant material

The investigated accessions (Table 1) are part of a greater *Capsicum* collection from the Faculty of Agricultural Sciences and Food in Skopje. The trial was performed on open field near Skopje in 2018, in a randomized block design with three replications with 10 plants in each replicate. The evaluation was focused on determining variability of several quantitative (weight, length, diameter and pericarp thickness) and qualitative (color at intermediate stage, color at mature stage, fruit shape, shape at pedicel attachment, shape at blossom end, cross-sectional corrugation) fruit traits determined according to the guidelines given in the Descriptors for *Capsicum* (IPGRI, AVRDC, CATIE, 1995).

Table 1. List of investigated kapiya type *Capsicum* accessions (code, local name, origin).

| No | Genotype code | Local name | Collection site |
|---|---|---|---|
| 1. | FZNH 001 | Kurtovska kapija | Sirkovo |
| 2. | FZNH 084 | Kapija | Krivogashtani |
| 3. | FZNH 096 | Bugarka | Strajanje |
| 4. | FZNH 170 | Ajvarski blag | Mustafino |
| 5. | FZNH 240 | Ajvarski | Rakitec |
| 6. | FZNH 250 | Ajvarski | Konche |
| 7. | FZNH 255 | Kurtovska kapija za ajvar | Viniche |
| 8. | FZNH 266 | Ajvarski | Nemanjica |
| 9. | FZNH 268 | Ajvarski | Sokolarci |
| 10. | FZNH 319 | Ajvarski | Belche |
| 11. | FZNH 344 | Ajvarski | Vinica |
| 12. | FZNH 362 | Ajvarski turski | Pribachevo |
| 13. | FZNH 393 | Ajvarski | Orizari |
| 14. | FZNH 519 | Kapija crvena | Drenovo |
| 15. | FZNH 528 | Industriski | Vinicka krshla |
| 16. | FZNH 537 | Ajvarski debel | Ilinden |
| 17. | FZNH 578 | Kapija | Kumarino |
| 18. | FZNH 635 | Kapija | Konjari |
| 19. | FZNH 717 | Slonovo uvo | Veljusa |

### Data analysis

Analysis of variance (ANOVA) was performed in order to identify significant differences among the means for the quantitative traits. In addition, two multivariate analyses were carried out, principal component analysis (PCA) and agglomerative hierarchical clustering (AHC) using XLSTAT Package 2014.5.03 (Addinsoft, 2014). The multivariate analyses included all data for quantitative and qualitative traits that were previously standardized (mean=0, SD=1).

## RESULTS AND DISCUSSION

### Analysis of quantitative and qualitative traits

Analysis of variance revealed significant differences among the genotypes for all traits (Table 2), revealing the presence of high genetic diversity. The average fruit weight ranged from 66.12 g in genotype FZNH 319 to 159.51 g for genotype FZNH 537. Fruit length ranged

from 12.46 cm in genotype FZNH 528 to 18.12 cm in genotype FZNH 268. Smallest fruit diameter was measured in genotype FZNH 268 (3.95 cm), while FZNH 001 (6.93 cm) had the widest fruits. All accessions had high average values for fruit wall thickness which is among the preferred parameters for processing. The means ranged from 4.11 mm in genotype FZNH 268 to 6.11 mm in genotype FZNH 266. Some of the accessions showed higher values for these traits in comparison with ones reported by Todorova (2007) and Tsonev et al. (2017) for kapiya type peppers. The influence of these traits on the potential economic significance for future breeding should be considered for detection and development of perspective lines.

Table 2. Descriptive statistics of quantitative fruit traits in 19 pepper genotypes.

| Genotype | Fruit weight (g) | | Fruit length (cm) | | Fruit diameter (cm) | | Pericarp thickness (mm) | |
|---|---|---|---|---|---|---|---|---|
| | X | Sx | X | Sx | X | Sx | X | Sx |
| FZNH 001 | 136.11 | 24.85 | 14.98 | 2.74 | 6.93 | 1.26 | 5.95 | 1.09 |
| FZNH 084 | 96.63 | 17.64 | 15.74 | 2.87 | 4.47 | 0.82 | 5.12 | 0.93 |
| FZNH 096 | 76.14 | 13.90 | 12.88 | 2.35 | 5.05 | 0.92 | 4.92 | 0.90 |
| FZNH 170 | 85.26 | 15.57 | 13.05 | 2.38 | 4.77 | 0.87 | 5.08 | 0.93 |
| FZNH 240 | 106.98 | 19.53 | 14.72 | 2.69 | 5.73 | 1.05 | 5.15 | 0.94 |
| FZNH 250 | 114.81 | 20.96 | 14.33 | 2.62 | 5.90 | 1.08 | 6.09 | 1.11 |
| FZNH 255 | 78.53 | 14.34 | 15.85 | 2.89 | 4.39 | 0.80 | 4.58 | 0.84 |
| FZNH 266 | 158.26 | 28.89 | 14.98 | 2.73 | 6.45 | 1.18 | 6.11 | 1.12 |
| FZNH 268 | 79.96 | 14.60 | 18.12 | 3.31 | 3.95 | 0.72 | 4.11 | 0.75 |
| FZNH 319 | 66.12 | 12.07 | 16.54 | 3.02 | 4.11 | 0.75 | 4.31 | 0.79 |
| FZNH 344 | 92.98 | 16.98 | 15.75 | 2.88 | 5.16 | 0.94 | 4.71 | 0.86 |
| FZNH 362 | 90.79 | 16.58 | 11.42 | 2.09 | 5.51 | 1.01 | 4.89 | 0.89 |
| FZNH 393 | 86.01 | 15.70 | 17.32 | 3.16 | 4.51 | 0.82 | 4.20 | 0.77 |
| FZNH 519 | 117.80 | 21.51 | 16.94 | 3.09 | 6.40 | 1.17 | 5.62 | 1.03 |
| FZNH 528 | 87.18 | 15.92 | 12.46 | 2.27 | 5.39 | 0.98 | 4.89 | 0.89 |
| FZNH 537 | 159.51 | 29.12 | 15.80 | 2.89 | 6.77 | 1.24 | 5.97 | 1.09 |
| FZNH 578 | 121.33 | 22.15 | 12.61 | 2.30 | 6.55 | 1.20 | 5.86 | 1.07 |
| FZNH 635 | 74.03 | 13.52 | 14.03 | 2.56 | 3.98 | 0.73 | 4.57 | 0.83 |
| FZNH 717 | 90.33 | 16.49 | 13.82 | 2.52 | 5.81 | 1.06 | 4.80 | 0.88 |
| LSD0.05 | 1.516 | | 0.156 | | 0.076 | | 0.077 | |

From the qualitative fruit characteristics, the color was recorded at two stages, at the intermediate stage (just before ripening) and on fully ripened fruits. Green and orange colors were present at the intermediate stage, while ripe fruits had red or dark red coloring. Triangular fruit shape is typical for kapiya peppers and it was dominant in the collection with exception of two genotypes (FZNH 268 and FZNH 319) that had elongated fruit shape. Truncate and cordate shape of pedicel attachment prevailed and lobate shape was recorded in only one genotype (FZNH 537). The shape of the blossom end was recorded as: sunken and pointed or blunt. In terms of cross-sectional corrugation most of the genotypes had intermediate corrugation, while some of them were only slightly corrugated (Table 3).

**Principal component analysis (PCA)**

Principal component analysis (PCA) revealed that the first three principal components explained 74.63% of the variation, since only those had eigenvalue above 1. The first principal component (PC1) explained 47.96% of total variation and was positively correlated with fruit diameter, pericarp thickness and fruit weight. Similar results for correlation of traits in the first component were obtained by Tsonev et al. (2017) in evaluation of Bulgarian pepper cultivars. From the qualitative traits, the strongest positive correlation with PC1 were observed for shape at pedicel attachment, fruit shape and shape

at blossom end. Also, Rivera et al. (2016) made similar observations in assessment of Spanish pepper landraces where fruit shape, color and shape at blossom end contributed the most in the first principal component. The second PC explained 15.00% of the variability and is mainly associated with the fruit length, intermediate color and cross sectional corrugation. The third principal component (PC3) explained 11.66% of the variation and was positively correlated with fruit color at maturity (Table 4).

Table 3. Frequency distribution of qualitative traits in evaluated *C. annuum* L. genotypes.

| Trait | Expression | No. of genotypes | Genotype |
|---|---|---|---|
| Fruit color at intermediate stage | Green | 10 | FZNH001, FZNH096, FZNH170, FZNH240, FZNH250, FZNH266, FZNH362, FZNH537, FZNH578, FZNH717 |
| | Orange | 9 | FZNH084, FZNH255, FZNH268, FZNH319, FZNH344, FZNH393, FZNH519, FZNH528, FZNH635 |
| Fruit color at maturity | Red | 11 | FZNH001, FZNH096, FZNH240, FZNH268, FZNH319, FZNH344, FZNH362, FZNH393, FZNH578, FZNH635, FZNH717 |
| | Dark red | 8 | FZNH084, FZNH170, FZNH250, FZNH255, FZNH266, FZNH519, FZNH528, FZNH537 |
| Fruit shape | Elongate | 2 | FZNH268, FZNH319 |
| | Triangular | 17 | FZNH001, FZNH084, ZNH096, FZNH170, FZNH240, FZNH250, FZNH255, FZNH266, FZNH344, FZNH362, FZNH393, FZNH519, FZNH528, FZNH537, FZNH578, FZNH635, FZNH717 |
| Fruit shape at pedicel attachment | Truncate | 7 | FZNH084, FZNH250, FZNH268, FZNH319, FZNH393, FZNH635, FZNH717 |
| | Cordate | 11 | FZNH001, FZNH096, FZNH170, FZNH240, FZNH255, FZNH266, FZNH344, FZNH362, FZNH519, FZNH528, FZNH578, |
| | Lobate | 1 | FZNH537 |
| Fruit shape at blossom end | Blunt | 15 | FZNH001, FZNH084, FZNH096, FZNH170, FZNH240, FZNH255, FZNH266, FZNH268, FZNH319, FZNH344, FZNH362, FZNH393, FZNH519, FZNH635, FZNH717 |
| | Sunken and pointed | 4 | FZNH250, FZNH528, FZNH537, FZNH578 |
| Fruit cross-sectional corrugation | Slightly corrugated | 7 | FZNH084, FZNH096, FZNH170, FZNH250, FZNH268, FZNH635, FZNH717 |
| | Intermediate | 12 | FZNH001, FZNH240, FZNH255, FZNH266, FZNH319, FZNH344, FZNH362, FZNH393, FZNH519, FZNH528, FZNH537, FZNH578 |

The phenotypic divergence was confirmed with PCA, visualized on the biplot (Figure 1) where investigated genotypes are dispersed in all four quadrants. Genotypes FZNH 319 and genotype FZNH 268 give the largest contribution to PC2 and are defined by high fruit length and orange intermediate color. The genotypes FZNH 537 and FZNH 266 are characterized with highest fruit weight. The accessions with lowest values for fruit diameter are clearly grouped in the lower area of the biplot (FZNH 268, FZNH 329 and FZNH 635).

Table 4. Principal component analysis based on fruit traits.

| Traits | PC1 | PC2 | PC3 |
|---|---|---|---|
| Fruit length | -0.417 | **0.748** | -0.417 |
| Fruit diameter | **0.905** | 0.030 | -0.310 |
| Fruit weight | **0.847** | 0.293 | -0.383 |
| Pericarp thickness | **0.900** | -0.002 | -0.254 |
| Intermediate color | -0.665 | **0.579** | 0.316 |
| Color at maturity | 0.457 | 0.232 | **0.510** |
| Fruit shape | **0.662** | -0.116 | 0.459 |
| Shape at pedicel attachment | **0.729** | 0.165 | 0.141 |
| Shape at blossom end | **0.617** | -0.102 | 0.141 |
| Cross-sectional corrugation | 0.523 | **0.644** | 0.274 |
| Eigenvalue | 4.796 | 1.500 | 1.166 |
| Variability (%) | 47.963 | 15.004 | 11.662 |
| Cumulative variability % | 47.963 | 62.966 | 74.628 |

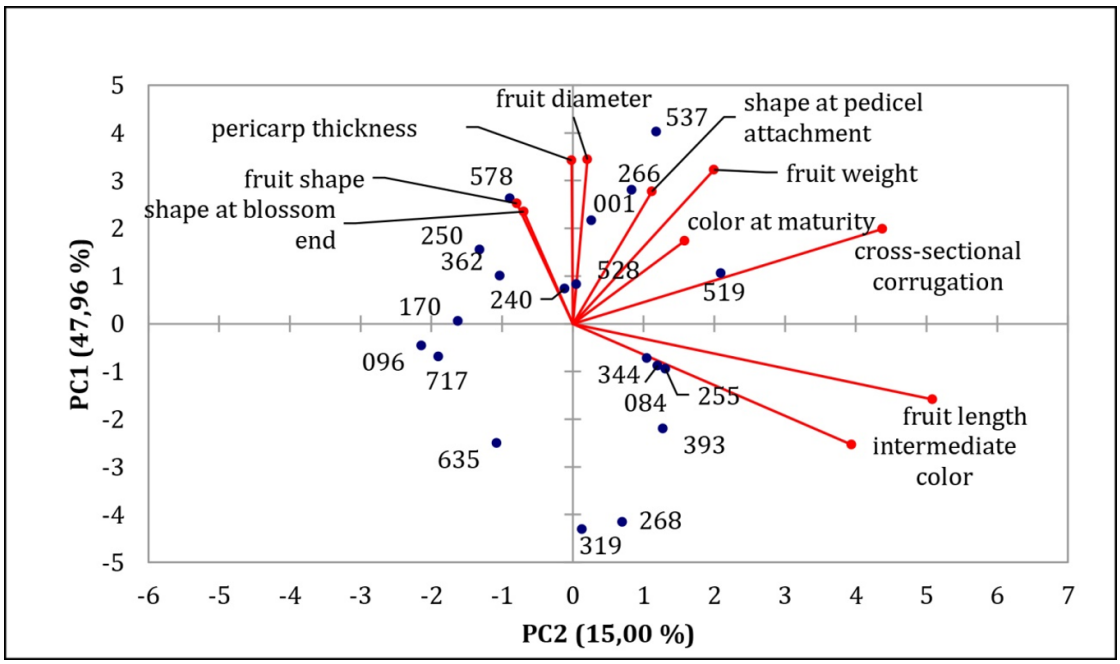


Figure 1. Biplot PCA of 19 kapiya genotypes and fruit traits.

**Cluster analysis**

The great intra and inter-specific variability in *Capsicum* should be helpful for breeding programs, through evaluation and clustering of accessions based on different traits (Ortiz et al., 2010; Danojevic and Medic-Pap, 2018). To determine the diversity among genotypes, agglomerative hierarchical clustering (AHC) was performed based on all quantitative and qualitative traits using Ward's agglomeration method and Euclidean distance. It resulted in grouping the genotypes in three clusters (Figure 2). The first cluster included the genotypes FZNH 319 and FZNH 268 which were the only ones with elongated shape, not typical for kapiya type pepper which mainly has triangular shape. The third cluster included 6 genotypes (FZNH 519, FZNH 537, FZNH 578, FZNH 266, FZNH 240 and FZNH 001) and these are characterized by mean fruit weight above 100 g, high fruit diameter (>5.7 cm) and the highest values for pericarp thickness (>5.15 mm). The rest of the genotypes belonged to the second cluster. Multivariate analysis based only on qualitative traits is not sufficient for classifying accessions (Ortiz et al., 2010), but combined with the

quantitative traits it represents a useful tool for grouping accessions with potential for future utilization (Lahbib et al., 2012; Parisi et al., 2013). Based on this analysis, it can be recommended that the genotypes from the third cluster can be further used for development of perspective lines.

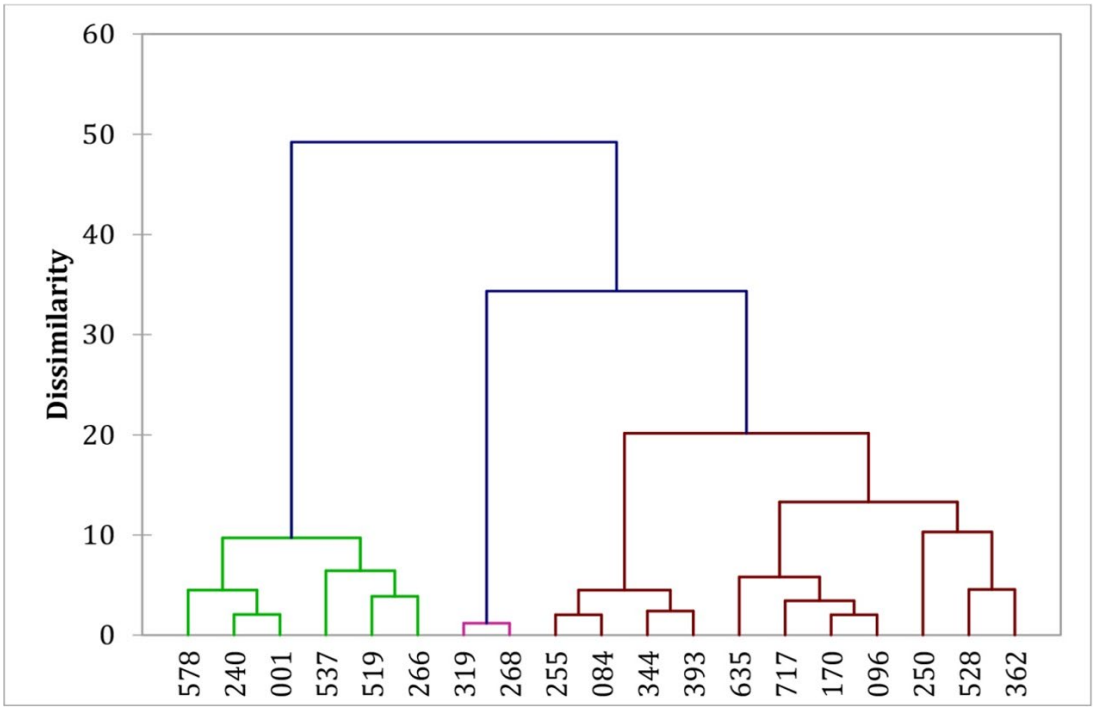


Figure 2. Dendogram obtained for 19 kapiya accession based on fruit traits.

**CONCLUSIONS**

The morphological evaluation of fruit traits in 19 kapiya type peppers from North Macedonia revealed useful insight in the diversity of this collection. The results give preliminary description and illustrate the potential of these genotypes for trait selection in further breeding programs. Based on these results, six of the evaluated genotypes (FZNH 519, FZNH 537, FZNH 578, FZNH 266, FZNH 240 and FZNH 001) can be of value in development of breeding lines, since the cluster analysis grouped them as most promising based on the yield associated traits (fruit weight, fruit diameter and pericarp thickness). As for inclusion of some genotypes in commercial production, recommendations can be made after additional evaluation of productive traits as well as resistance to biotic and abiotic factors.

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