Original scientific paper

VARIATION OF FRUIT MORPHOLOGICAL TRAITS IN *CAPSICUM ANNUUM* L. GERMPLASM COLLECTION FROM NORTH MACEDONIA

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ABSTRACT

The aim of this research was to evaluate the phenotypic divergence of 33 local pepper landraces from North Macedonia based on their quantitative and qualitative fruit traits. According to the vernacular names they belong to the longum group and are traditionally consumed mostly in technological maturity. The experiment was laid out in randomized block design in three replications in 2018. Six quantitative fruit traits were evaluated: fruit length, fruit width, fruit weight, fruit pedicel length, fruit wall thickness and number of locules, as well as several qualitative traits: colour at intermediate stage, colour at mature stage, fruit shape, shape at blossom end, cross-sectional corrugation, ripe fruit persistence – pedicel with fruit and pedicel with stem. The PCA analysis identified that two principal components explain more than 77% of the variability based on the quantitative fruit parameters. The cluster analysis classified the accessions in three clusters, where the third cluster grouped seven local landraces that had highest values for fruit width, fruit weight and pericarp thickness as major yield components. It can be concluded that the results obtained for the fruit variability in the investigated 33 local pepper landraces from North Macedonia provided valuable information about the diversity of the collection. Furthermore, the local landraces identified in cluster three can be considered as potential source for selection of preferred traits or for further utilization in development of recommendations for direct production in the rural areas.

Key words: Capsicum, fruit traits, principal component analysis, cluster analysis.

INTRODUCTION

Out of the five domesticated species belonging to the genus Capsicum, the most prevalent in south-eastern Europe are the *Capsicum annuum* L varieties. It is assumed that the introduction of peppers in the Balkans was first made in Macedonia from where it was spread to the other neighbouring territories, by the ottomans in the 16th century (Jankuloski, 1997). Since then, here, as well as in the world, peppers are widely grown by the farmers and well accepted by the consumers, thus becoming one of the most important vegetables in the everyday diet, all year around (Dorego & Dorego, 2016).

The continued human manipulation enhanced the natural selection processes, resulting in development of versatile forms with specific characteristics in terms of pod shape, colour, pungency, aroma, flavour (Bosland & Votava, 2012). The long tradition in pepper production in the region and the dominating structure of smallholder farms, contributed in maintaining

rich pepper diversity. Most of the small farmers in the Balkan maintain at least 3-4 local varieties (Ivanovska & Andonov, 2018; Ilic et al., 2013; Todorova, 2007). Many studies evaluated the variability of local landraces and identified their potential for further use in breeding activities or their potential for cultivation in areas of origin where they are well adapted to the local conditions (Lavina et al., 2013; Lopez Castilla et al., 2019; Martinez-Ispizua et al., 2022; Nankar et al., 2020; Rivera et al., 2016, Madosa et al., 2010; Habtie et al., 2017; Lahbib, 2013). Therefore, it is first necessary to describe the phenotypic variations of local or regional interest based on agronomic potential or fruit quality, which can be useful raw material for generating and selecting improved material (Santiago-Luna et al., 2018).

Multivariate analyses are acknowledged as useful statistical tools for appropriate evaluation of germplasm, as well as for classification of genotypes based on their fruit traits (Drvoshanova et al., 2021; Sandeva Atanasova et al., 2021; Habtie & Dejene, 2020; Danojevic & Medic-Pap, 2018; Lakshmi Tirupathamma et al., 2018; Santiago-Luna et al., 2018; Naegele et al., 2016).

Therefore, the aim of this research was to evaluate the phenotypic diversity of 33 local pepper landraces from North Macedonia, that have not been evaluated before, based on the fruit traits. It is expected that the results will provide valuable information for efficient conservation of these resources, as well as contribute in identifying material suitable for further breeding activities.

MATERIALS AND METHODS

Subject of this research are 33 pepper landraces which are part of the collection of the Faculty of Agricultural Sciences and Food in Skopje, that have not been previously evaluated. The trial was conducted on open field in 2018, in Dolno Lisiche, Skopje area. The experiment was laid out in randomized block design in three replications with 20 plants per replicate, planted with distance of 30 cm in row and 50 cm between rows. The observations were made on randomly selected 10 physiologically mature fruits per plot, according to the guidelines given in the Descriptor for Capsicum (IPGRI, AVRDC, CATIE, 1995). Six quantitative fruit traits were evaluated: fruit length (FL, cm), fruit width (FW, cm), fruit weight (F mass, g), fruit pedicel length (FPL, cm), fruit wall thickness (FWT, cm) and number of locules (NL). Several qualitative traits were also observed: colour at intermediate stage, colour at mature stage, fruit shape, shape at blossom end, cross-sectional corrugation, ripe fruit persistence – pedicel with fruit and pedicel with stem. The qualitative traits were analysed through frequency distribution, where the mean value for each landrace was accepted as the most frequent representation of the traits after evaluating 30 samples. Their frequencies are presented for better description of the clusters. A Principal Component Analysis (PCA) with consideration of the quantitative fruit traits was carried out in order to describe phenotypic divergence and to identify the variables with highest descriptive value. Agglomerative hierarchical clustering using Ward's method and Squared Euclidean distance was also performed. All data for the multivariate analyses were previously standardized (mean = 0, SD = 1) and analysed with XLSTAT Package 2014.5.03 (Addinsoft, 2014).

Table 1. List of investigated Capsicum landraces from North Macedonia (code, local name, origin)

No	Genotype code	Local name	Collection site
1.	FZNH 249	Blag kavardzik	Viniche
2.	FZNH 259	Lut kavardzik	Viniche
3.	FZNH 020	Kavardzik	Dolno Lisiche
4.	FZNH 547	Kavardzik	Tabanovce
5.	FZNH 019	Kavardzik	Creshevo
6.	FZNH 281	Bel sivrija	Ziganci
7.	FZNH 052	Sivrija tenka za susenje	Karbinci
8.	FZNH 615	Kozji rog blag	Kratovo
9.	FZNH 539	Kavardzik bel	Ilinden
10.	FZNH 136	Sivrija blag	Kozjak
11.	FZNH 566	Kozji rog blag	Mlado Nagorichane
12.	FZNH 172	Kozji rog blag	Selce
13.	FZNH 213	Kozji rog	Smilkovci
14.	FZNH 075	Tenok sivrija	Tarinci
15.	FZNH 315	Bela duga	Vinica
16.	FZNH 208	Bela duga	Viniche
17.	FZNH 372	Kozji rog blag	Nivichani
18.	FZNH 287	Bela duga	Novoselani
19.	FZNH 596	Kozji rog	Stajkovci
20	FZNH 070	Blag bela duga	Sarchievo
21	FZNH 597	Bela duga	Stajkovci
22	FZNH 579	Bela duga blag	Bashino selo
23	FZNH 389	Bel dolg blag	Burilchevo
24	FZNH 381	Bel dolg	Dolni Podlog
25	FZNH 705	Tenka dolga	Kalaslari
26	FZNH 706	Tenka dolga	Kalaslari
27	FZNH 158	Crn tenok	Amzabegovo
28	FZNH 050	Tenok za przenje	Argulica
29	FZNH 087	Bel blag	Buchin
30	FZNH 357	Gradinarski piper	Trabotivishte
31	FZNH 230	Tenok blag	Konche
32	FZNH 347	Tenok blag	Vinica
33	FZNH 169	Bel prchest	Lozovo

RESULTS AND DISSCUSION

The Principal Component Analysis showed that the first two components accounted for 77.926% of the variation, where the first principal component (PC1) contributed 52,319%, and the second principal component (PC2) contributed 25.607% to the total variation. Among the studied characters in PC1, the highest positive correlation had fruit width, fruit weight and pericarp thickness (Table 2). Similar observations for Balkan local landraces were obtained by other authors that evaluated fruit traits in pepper (Drvoshanova et al., 2021; Sandeva Atanasova et al., 2021; Nankar et al., 2020; Tsonev et al., 2017; Madosa et al., 2010). The second PC had strong positive correlation with fruit length and pedicel length. The visualization on the biplot area identifies FZNH169, FZNH539 and FZNH249 as landraces with lowest values for fruit length. On the right side of the biplot the accessions with most preferred values are grouped, considering their role as major yield components.

Table 2. Principal component analysis for fruit characters of the studied landraces

Traits	PC1	PC2
Fruit length	-0.008	**0.946**
Fruit width	**0.957**	-0.179
Fruit weight	**0.950**	0.019
Pedicel length	0.547	**0.741**
Pericarp thickness	**0.902**	-0.241
Number of locules	0.456	-0.058
Eigenvalue	3.139	1.536
Variability (%)	52.319	25.607
Cumulative %	52.319	77.926

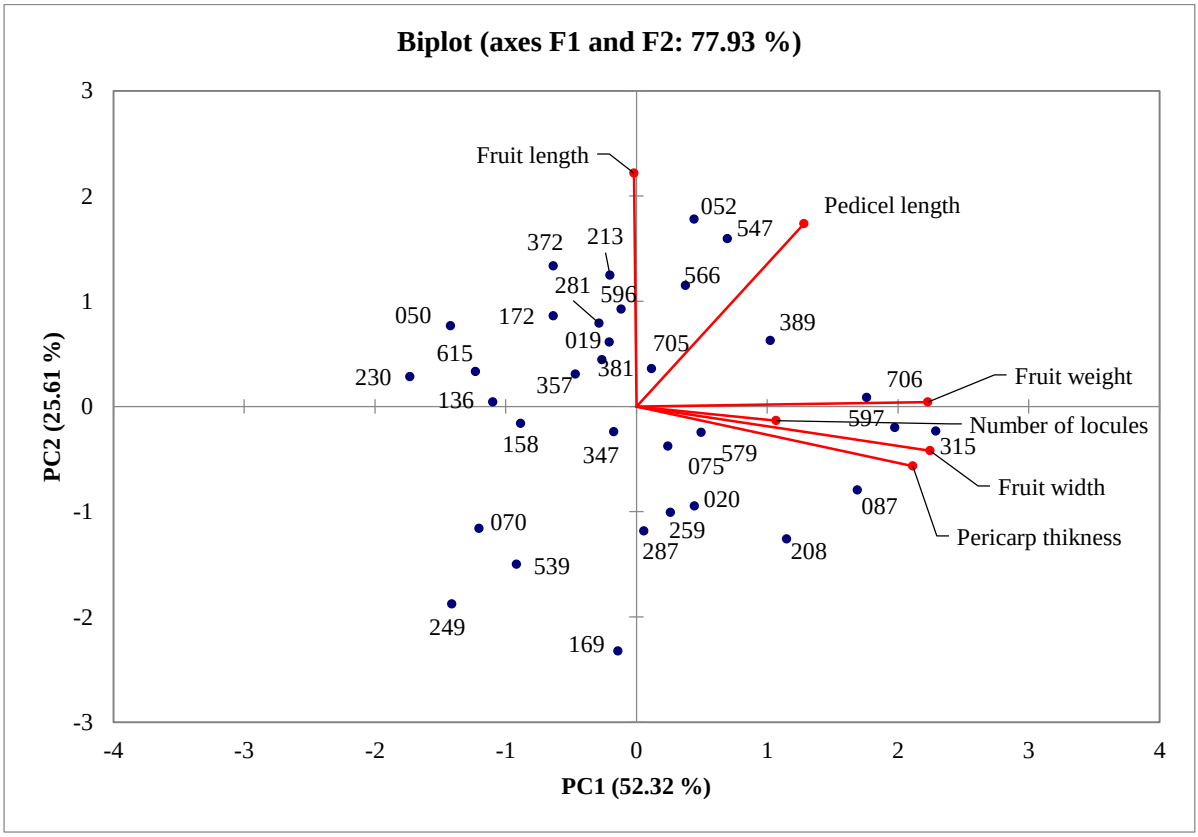

Figure 1. Biplot graphic showing relative position of 33 Capsicum landraces based on PCA scores

The information about a germplasm variability or traits of interest helps in effective management of gene banks, but also in increased efficiency for further utilization of accessions in various breeding processes (Martínez-Ispizua et al., 2022; Parisi, 2013; Santos et al., 2019; Todorova, 2007). Agglomerative hierarchical clustering was performed, using Ward's method and the standardized Euclidean distance as a dissimilarity measure. In order to obtain better classification of the evaluated germplasm, the results for fruit length (FL) were omitted from this analysis due to the fact that almost all landraces have long fruits but also because the PCA revealed slight negative correlation with this trait in the first principal component as a major source of variation. The cluster analysis resulted in grouping the landraces in three clusters (Figure 2). The first cluster included 8 local populations with lowest values for fruit width, fruit

weight and pericarp thickness. On the opposite, the third cluster contained 7 local populations with highest values for these traits and can be considered as a source for selection of preferred traits. This information can also be of use in exploring possibilities for direct production in the area of origin, since the pericarp thickness is an important trait related to fruit quality since it increases the fruit firmness, thus tolerating damages and enabling commercialization for a longer period (Santos Pessoa et al., 2018)

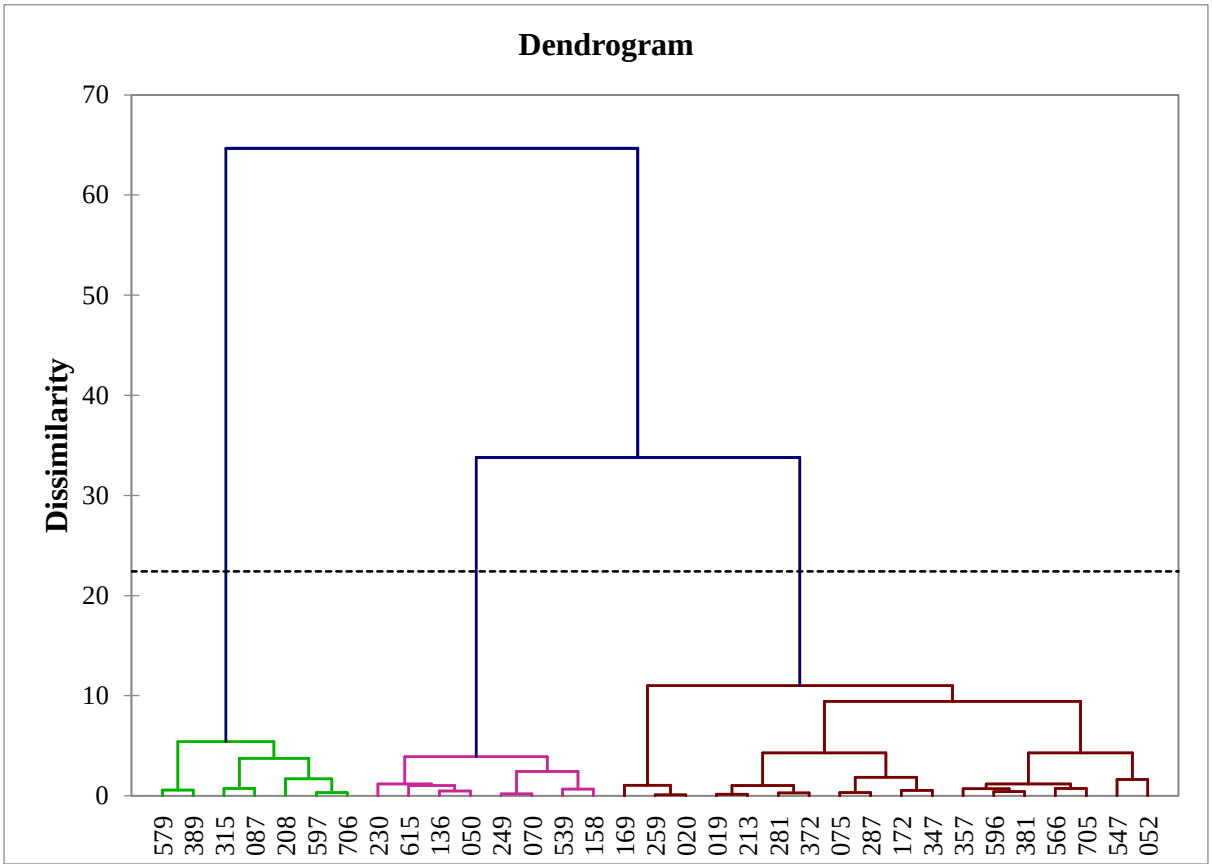

Figure 2. Classification of 33 local Macedonian pepper landraces based on analysed fruit traits

Table 3. Range values for the analysed quantitative fruit traits

Quantitative traits	*Range values*		
	Cluster I	**Cluster II**	**Cluster III**
Fruit width (cm)	1.54 – 2.78	2.31 – 3.47	3.38 – 4.76
Fruit weight (g)	17.12 – 45.30	35.73 – 57.75	65.62 – 105.88
Pedicel length (cm)	2.53 – 3.64	2.68 – 5.20	3.78 - 4.44
Pericarp thickness (mm)	2.08 – 3.06	2.54 – 3.72	3.66 – 4.73
Number of locules	2.10 – 2.40	2.23 – 2.80	2.24 – 2.62

In order to give better description of the investigated germplasm in each cluster, the range values for the quantitative traits are given in Table 3, along with frequency distribution for the qualitative characters (Table 4). The frequency distribution shows wide variability among the investigated local landraces. For the colour before the ripening stage, green was predominant in the collection (39%), while in the third cluster the accessions had only white and yellow fruits. The most frequent colour in physiological maturity was red, followed by dark red and light red, while one landrace in cluster three had orange colour. Regarding the fruit shape most

of the accessions had elongated fruits (84.9%), while 5 accessions had fruit with triangular shape and most of them are grouped in the third cluster. In addition, 63.6% of the genotypes had fruits with pointed blossom-end while 36.4% had blunt end fruit types and were most frequent in the third cluster. In terms of fruit cross-sectional corrugation, most of the accessions were intermediate (78.8%). The persistence of the pedicel with the fruit and the stem are traits that facilitate the harvesting processes and the postharvest manipulation with the fruits. From the investigated germplasm 57% had intermediate persistence with the fruit and the stem. In the third cluster three accessions had slight persistence with the stem and three had intermediate. This is to be considered as a value for easier harvesting, particularly in local small-holder production where the availability of workforce is limited usually on family members.

Table 4. Frequency distribution of qualitative traits for each cluster and total distribution of each trait among the investigated germplasm

Qualitative traits	***Frequency distribution***			**Total**
	Cluster I	**Cluster II**	**Cluster III**	**%**
Fruit color at intermediate stage				
White	/	2	2	21.1
Yellow	/	5	5	30.3
Green	6	7	/	39.4
Orange	2	4	/	18.2
Fruit color at maturity				
Orange	/	1	/	3
Light red	2	3	3	24.2
Red	2	7	4	39.4
Dark red	4	7	/	33.3
Fruit shape				
Elongate	8	17	3	84.9
Triangular	/	1	4	15.1
Fruit shape at blossom end				
Pointed	8	12	1	63.6
Blunt	/	6	6	36.4
Fruit cross-sectional corrugation				
Slightly corrugated	1	1	3	15.1
Intermediate	6	16	4	78.8
Corrugated	1	1	/	6.1
Ripe fruit persistence -Pedicel with fruit				
Slight	2	4	1	21.2
Intermediate	5	9	5	57.6
Persistent	1	5	1	21.2
Ripe fruit persistence -Pedicel with stem				
Slight	4	4	3	33.3
Intermediate	4	12	3	57.6
Persistent	/	2	1	9.1

CONCLUSIONS

The results obtained for the fruit variability in the investigated 33 local pepper landraces from North Macedonia provided valuable information about the diversity of the collection. They will contribute in effective selection of desirable traits for future breeding activities, as the PCA and AHC analysis confirmed the potential of the landraces in the third cluster.

Furthermore, they can be subjected to broader study in order to explore the possibilities for wider cultivation.

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