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Phenotypic diversity and fruit characterization of eggplant (*S. melongena* L.) landraces in IPGR, Sadovo genebank

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Abstract

Masheva, V., Uzundzhalieva, K. & Sabeva, M. (2023). Phenotypic diversity and fruit characterization of eggplant (*S. melongena* L.) landraces in IPGR, Sadovo genebank. *Bulg. J. Agric. Sci., 29*(5), 925–931

Environmental changes, including biodiversity loss, threaten agricultural production. The preservation and study of traditional germplasm collections is an essential element in the expansion of ecotypes. In recent years, eggplant has received a lot of interest as a functional food, falling among the top ten vegetables as a source of phenolic compounds that act as antioxidants. At the Institute of Plant Genetic Resources, Sadovo, 22 local varieties of eggplant from four regions of Bulgaria were studied according to 17 quantitative and qualitative characteristics from the eggplant descriptor.

Plant fruit weight recorded a highly positive significant correlation with width (r = 0.802**). Similarly, significant positive correlations were identified between days to flowering and fruit set (r = 0.867**) and between leaf length (r = 0.607**) and leaf width (r = 0.593**) and crude protein.

The quality of the fruit is considered most important and therefore total sugar, crude protein and dry matter content are determined. Significant differences were observed, with A9E1156, B2E0302, and A8E0531 being high in protein, A8E0604, B6E0332, and A9E0537 having prominent sugars, while A7E0313, B4E0126, and A8E0586 were found to be high in dry matter.

The results showed significant morphological and biochemical differences between the evaluated accession foundations for further breeding programs and a major source of agricultural biodiversity.

Keywords: eggplant; *Solanum melongena* L.; phenotype; landrace; biodiversity

Introduction

In connection with the food security the eggplant (*Solanum melongena* L.), appeared to be a very valuable crop. Eggplant is among the top 10 plant species in terms of oxygen radical absorption capacity (Salerno et al., 2014; Kandoliya et al., 2015) due to high levels of phenolic acids in the mesocarp and anthocyanins in the exocarp (Ribarova 2005; Plazas et al., 2013; Stommel et al., 2015). These substances possess antioxidant activity and are known for their beneficial properties for human health.

The Global Strategy for the Conservation and Use of Eggplants (2022), includes not only priority actions for conservation, but also for sustainable use of eggplant genetic resources. Totally 15910 accessions, including the tree cultivated species and some crop wild relatives are maintained in 110 collections in 76 countries (Global Strategy for the Conservation and Use of Eggplants, 2022; Munoz-Falcon et al., 2009).

According to Genesis (global database) and WIEWS (Global information system and early warning for PGRFA) for the existing eggplant collections the most commonly represented type is the brinjal eggplant (209 accessions). The wild relatives of the eggplant are maintained only in some collections (Global Strategy for the Conservation and Use of Eggplants, 2022). In the National genebank in IPGR-Sadovo are maintained 178 eggplant accessions and thus it is the 6-th biggest collection in Europe.

Differentiated by farmers during a selection process, local varieties represent a great genetic heritage as a source of agricultural biodiversity (Singh, 2018; Nan et al., 2021). They are well adapted to the specific agroclimatic conditions and are suitable for biological production (Gonzalez-Cebrino et al., 2011; Ribes-Moya et al., 2018). They possess high genetic diversity, local adaptation, resistance to pathogens and very good organoleptic characteristics, nevertheless they give lower yields and lack of uniformity (Bota et al., 2014; Singh 2018; Carillo et al., 2019).

The characterization of the population structure and genetic diversity of the local varieties and local germplasm will contribute to prevention of genetic erosion (Gramazio et al., 2019) and will ensure future resources for selection programs. Phenotyping is the first step in the description and classification of the local genetic resources (Smith & Smith 1989; Cakir et al., 2017). As a result the low level of variation of the commercial eggplant varieties, mainly in the developed countries, investigation and structuring of collections from the traditional varieties are turned to be a key element for extension of the ecotypes and stimulation of the conservation of the biodiversity of the crop (Martínez-Ispizua et al., 2021).

The fast development of the genomics gave to the breeders the possibility to create varieties with high yields and resistant to stress. Only the lack of sufficient phenotyping data could prevent this activity (Zhang & Zhang, 2018). The presence of detailed description of the characteristics and nutrition qualities of the traditional eggplant varieties should be of significant interest, because of the high phenotyping diversity of the local varieties (Gosa et al., 2019).

The aim of the current study is to investigate the collection of local eggplant varieties in the National Genebank of Bulgaria (in IPGR – Sadovo) and to evaluate the genetic diversity of the genplasm as a base for future breeding programs and source of agricultural biodiversity**.**

Material and Methods

The field trial was carried out in 2020 and 2022, with 22 local eggplant accessions from the National Genebank in IPGR–Sadovo. The experiment was conducted at Institute of Plant Genetic Resources, Sadovo, Bulgaria (42°07 N and 24°56′ E). The soil was heavy sandy loam with an alkaline reaction (pH – 7.7–7.9) and humus content – 2.54–2.75%.

The seeds from the accessions were sown and plants were grown in the experimental field of IPGR – Sadovo, in block method with two repetitions with 10 plants each. Plants were grown in single rows with 60 cm between rows and 40 cm between plants. Dropping irrigation was applied and it supplies 100% from the evaporation of the crops (ETc). Fertilizers were applied with the irrigation. The characterization data of the plants, leaves and flowers were taken from 10 plants from each accession. The characteristics of the fruit were taken from 10 different fruits, typical for the local variety in full maturity, 2.5–3 months after planting in July and August according to the variety.

List of the accessions with their passport data are given in Table 1.

The data about 16 quality and quantity traits were evaluated and classified according to the International Board for Plant Genetic Resources descriptors (IBPGR 1990) for eggplant (Table 2).

Statistical analysis

The data analysis was done by correlation analyses based on the degree of similarity of the accessions and Principal Component Analysis (PCA), using the SPSS (IBM SPSS Statistics 19 software). The values of the load factors that apply to the principal components are eigenvalues >1.0. Data with loading coefficients > 0.6 were defined as core principal components (Balkaya et al., 2009, Cakir et al., 2017).

Table 1. Abbreviation, germplasm collection code and original location.

№	Genbank code	Original location
1	A7E0262	Kresna, Blagoevgrad, Bulgaria
2	A7E0281	Kresna, Blagoevgrad, Bulgaria
3	A7E0312	Karnalovo, Blagoevgrad, Bulgaria
4	A7E0313	Karnalovo, Blagoevg, Bulgaria
5	B2E0303	Trud, Plovdiv, Bulgaria
6	B4E0066	Staro Zelezare, Plovdiv, Bulgaria
7	B4E0126	Chernogorovo, Pazardzhik, Bulgaria
8	B2E0019	Beguntzi, Plovdiv, Bulgaria
9	B2E0302	Trud, Plovdiv, Bulgaria
10	A9E1156	Oriahovo, Haskovo, Bulgaria
11	A9E1431	Lubimetz, Haskovo, Bulgaria
12	A8E0552	Ierusalimovo, Haskovo, Bulgaria
13	A8E0534	Lubimetz, Haskovo, Bulgaria
14	A7E0525	Ierusalimovo, Haskovo, Bulgaria
15	A8E0602	Tzarevo, Burgas, Bulgaria
16	A8E0604	Tzarevo, Burgas, Bulgaria
17	A9E0537	Totleben, Pleven, Bulgaria
18	B6E0332	Belovo, Pleven, Bulgaria
19	A8E0586	Goliamo Krushevo, Yambol, Bulgaria
20	A9E1416	Gorno Boshevo, St. Zagora, Bulgaria
21	B0E0281	Svoboda, Stara Zagora, Bulgaria
22	B0E0282	Svoboda, Stara Zagora, Bulgaria

Table 2. List of the descriptors used for phenotyping according to the International Board for Plant Genetic Resources descriptors (IBPGR 1990) for eggplant

Descriptors	**Unit/Scale**
Plant morphology	
Length	cm
Branch	**number**
Leaf morphology	
Length	cm
Width	cm
Flowers morphology	
Corolla diameter	cm
Corolla colour	1. White; 2. Light violet; 3. Violet; 4. Dark violet
Fruit morphology in commercial maturity	
Length	cm
Width	cm
Weight	g
Shape	1. Globular; 2. Ovoidal; 3.Ovobal; 4. Pear shape 5. Deck shape; 6. Ellipsoid; 7. Cylindric
Fruit color	1. Green; 2. Milk white; 3. Deep yellow; 4. Fire red; 5; Skarlet red; 6. Lila grey; 7.Purple. 8. Purple black; 9. Black
Pulp colour	1. White 2. Greenish white 3. Intermediate
Fruit storage suitability	
Fruit dry matter	%
Fruit protein content	%
Fruit sugar	%
Vegetative	
Flowering period	days
Fruit formation period	days

Results and Discussion

Agromorphological Characterisation

The results for study morphological traits are shown in Table 3. The plant height varies from 59,75 cm (A8E0552) to 89,05 cm (A8E0604) (Table 3). Eggplants with Spanish origin (Kaushik et al., 2016), are 69.7 cm to 111.7 cm height. Twenty two accessions with origin from Pakistan are with plant height between 10.1 cm to 72.1 cm (Zohaib et al., 2022). Accessions with earlier or later blossom are A7E0312 и A8E0552, respectively 78.4 and 102.2 days. The leaf length varies from A9E1416 (25,44 cm) to A7E0262 (15,18 cm) Leaf width is from 9 cm (A7E0262) to 23,04 cm (A9E1156). With biggest average leaf size are B6E0332 and B4E0066 accessions. The investigations of eggplant accessions with origin from China, (Xu H. et al., 2021), was established leaf length from 11.20 cm–37.0 cm and leaf width 4.70 cm –29.78 cm.

In their research Zohaib et al. (2022) point out that the color of the flowers is dark violette to white. The color of the flowers of the accessions, included in our study varies from pale violette, violette to dark violette (Figure 1)

Most of the accessions are with pale violette flowers – 49.99%. With violette color are 40.92% and with dark violette – 9.09%. Light violet colours are observed in plants with dark violet, striped and violet fruits, violet colors – in plants with dark violet, striped and white fruit specimens and dark violet colors only in plants with violet fruits.

The most important characteristics of the eggplants are connected with fruits. The variation in fruit shape is determined by the correlation between its length and width, curving, shape of the fruit top, as well as the color of the pericarp. The fruit color in commercial maturity is quite variable (dark volette, violette, white or green), with or without stripes. In

Table 3. Estimates of variability in eggplant landraces

Characters	Mean	Maximum	Minimum	Difference	SD	CV %
Plant length	71.10	59.75	89.05	29.30	6.27	8.82
Brunch number	7.20	7.20	9.60	2.4	0.81	8.62
Leaf length	22.30	25.44	14.62	10.82	4.44	19.90
Leaf width	16.12	23.04	10.50	12.54	3.68	22.83
Flow diameter	4.98	6.04	3.78	2.26	0.61	12.27
Fruit length	18.58	20.84	11.10	9.74	3.41	18.57
Fruit width	7.97	11.44	5.64	5.80	1.45	18.19
Fruit weight	399.62	500.50	259.00	241.50	72.06	18.03
Flowering time	87.67	95.70	78.40	17.30	7.45	8.50
Fruit formation	83.59	100.00	72.55	27.45	5.52	6.60
Fruit protein	14.37	10.88	7.35	3.53	2.58	17.95
Fruit sugars	3.23	6.06	2.37	3.69	1.27	39.32
Fruit dry matter	9.03	10.88	7.35	3.53	1.17	12.97

full maturity the fruits produce preliminary violette anthocyanins due to the biosynthesis of orange pigments from the group of the karothinoides (Liu et al., 2018; Barchi et al., 2019).

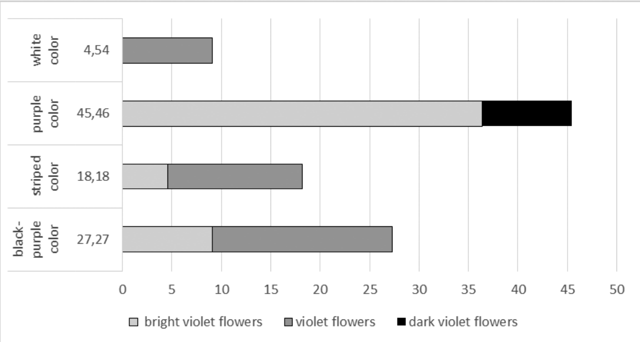

Fig. 1. Color of fruits and flowers

The local eggplant varieties, included in the study, are with dark violette, violette and white fruit color, with or without stripes (Figure 1). The fruits with violette color are the highest percent – 45.46%. The fruits with dark violette fruit color are 22.27%, with white – 9.09% and with stripes – 18.18%.

According Husnudin et al. (2019), the fruit shape could be round (with equal length and width), ovate (slightly longer than wide), inverse ovate (slightly longer than wide), pear-shaped, ellipsoid (twice longer than wide) and cylindrical (several times longer than wide In our collection the accessions are predominantly with ovate – 54.54% and inverse ovate shape – 27.28% and white pulp – 32.78% (Figure 2).

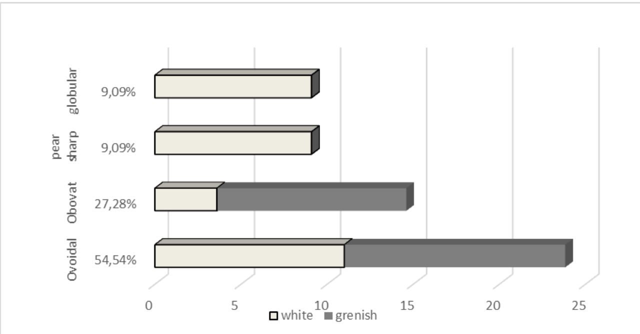

Fig. 2. Longitudinal shape and pulp color

Increased interest in food security has placed eggplant among the top 10 functional foods for its high antioxidant capacity. The chemical composition and nutrient qualities of fruits and vegetables are a major factor they to be considered as healthy and tasty food. For example, in Turkey, the small elliptical, or round eggplant varieties are used for conservation or stuffing; the long, cylindrical varieties with high content of dry substances are for grilling, frying or stuffing, large round or long oblong types are for stewing or frying (Cakir et al., 2017; Tümbilen et al.,2011). The distribution of dry substances, crude protein and sugars in the studied accessions is given in Figure 3. With high level of dry substances – 10.88% are A7E0313, B4E0126 and A8E0586 accessions. With high content of crude protein are A9E1156, B2E0302 and A8E0531 accessions. Sugars between 4.59% to 6,06% are established in A8E0604, B6E0332 and A9E0537.

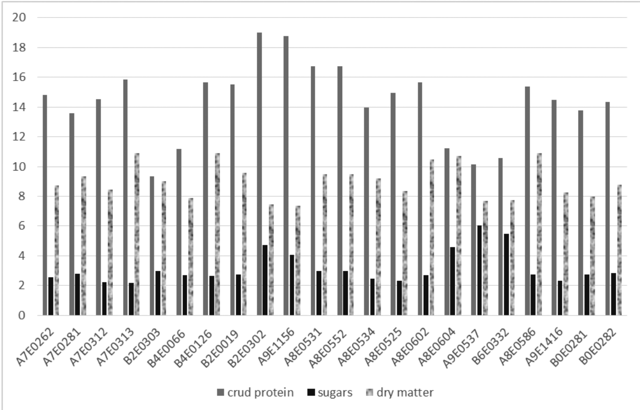

Fig. 3. Fruit storage sustainability

For evaluation of the significance of the linkage between the quantitative traits a correlation analysis of 13 traits was done. Pairwise coefficients showed positive correlation and statistical significance for 13 pairs of traits out of 78 examined (Table 4).

The most representative positive correlations were observed between flowering days and fruit formation days, fruit width versus weight, and leaf length versus width. The average fruit weight per plant shows strong positive correlation with the fruit width ($r = 0.802^{**}$) (Table 4).

The similar positive correlations were established between days to flowering and fruit formation ($r = 0.867^{**}$) and between the leaf length ($r = 0.607^{**}$) and width ($r = 0.593^{**}$) and the protein content.

Negative, but strongly significant correlation between the number of days to 50% flowering (r = – 0.387), fruit formation (r = -0.364) and plant height was observed. The same type of correlation was recorded between the sugars and dry matter (r = -0.383) and length and width of the fruit (r = – 0.242).

Table. 4. Significance of the linkage between the quantitative characters

1	1												
2	0.867**	1											
3	-0,387	-0,364	1										
4	-0,346	-0,356	0,348	1									
5	-0,193	-0,225	0,469*	0,481*	1								
6	-0,336	-0,301	0,516*	0,480*	0,913**	1							
7	-0,205	-0,165	0,488*	0,518*	0,470*	0,551**	1						
8	0,233	0,026	0,07	-0,048	0,306	0,278	0,205	1					
9	-0,25	-0,135	-0,154	0,222	0,261	0,32	-0,02	-0,242	1				
10	-0,294	-0,218	0,001	0,177	0,403	0,467*	-0,007	0,038	0,802**	1			
11	-0,261	-0,277	0,556**	0,416	0,607**	0,593**	0,432*	0,151	-0,231	-0,226	1		
12	0,222	0,051	-0,282	-0,287	0,259	0,229	-0,33	0,301	0,357	0,510*	-0,287	1	
13	0,287	0,397	0,024	0,262	0,017	-0,05	0,061	-0,109	0,052	-0,032	0,092	-0,383	1

*1. flowering period; 2. fruit formation period; 3. plant height; 4. branch number; 5. leaf length; 6. leaf width; 7. corolla diameter; 8. fruit length; 9. fruit width; 10. fruit weight; 11. fruit protein;12. fruit sugars; 13. dry matter

The Principal Component Analysis (PCA) was used to reveal the common differences between the genotypes as values, which show the traits that can be used for genotype differentiation (Balkaya et al., 2010). For that study PCA of eggplant populations was done, including the following traits – plant height, period of 50% flowering, period of fruit formation, number of branches, length and width of the leaves, length and width of the fruits and fruit weight. The proportions and the variations are shown in the first three PC axes, which correspond with values greater than 1.

The results of the principal component analysis (PCA) in this study have reduced the characters observed into tree main components that have an eigenvalue > 1 and can explain the diversity of the experiment material by 74.62 % of total variability in 22 accessions involving the studied traits (Table 5).

Table. 5. Principal component coefficients of each trait in local eggplant populations

PC Axis			
Eigen values	3.88	1.81	1.73
Explained proportion of variation (%)	38.83	18.07	17.30
Cumulative proportion of variation(%)	38.83	56.90	74.20
Traits	PC1	PC2	PC3
Plant length	-0.585	0.573	0.445
Flowering period	0.624	-0.374	0.345
Fruit formation period	-0.560	0.597	0.318
Branch number	0.671	-0.187	0.018
Leaf length	0.836	0.314	0.215
Leaf width	0.907	0.261	0.139
Corolla diameter	0.637	-0.094	0.437
Fruit length	0.164	0.320	0.628
Fruit width	0.390	0.451	-0.728
Fruit weigh	0.530	0.682	0.363

The first basic component axes represent 38.38% from the variation, while the second and the third are respectively 18.07% and 17.30%.

In this study, traits with high coefficients in the first, second and third principal components should be considered more important as these axes explain the largest proportion of the total variance. Although, there are no clear guidelines for determining the significance of an exact coefficient, one basic rule is to accept and consider significant coefficients > 0.6 as having a sufficiently large effect (Balkaya et al., 2009). Traits with high coefficients were: leaf width (0.907), leaf length (0.836), flower diameter (0.637), days to flowering (0.624) and branching (0.624) for principal component 1; fruit weight (0.628) for the second component and fruit width (-0.728) and fruit length (0.628) for the third principal component. These characteristics are considered the most important as they define the axes that explain 73.38% of the total variance (Table 5, Figure 4). In the present study, PCA identified fruit and leaf characters as the most important traits that supported the greatest amount of variability among genotypes.

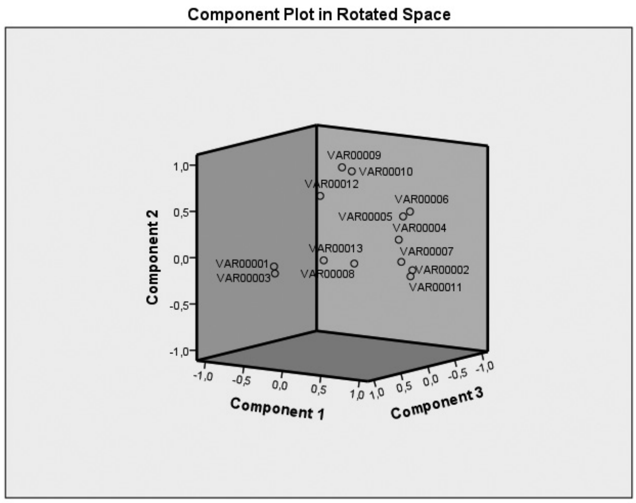

Fig. 4. Scatter plot constructed at the basis the first three principal component axes, which contain 74.62% of total variation

This separation of accessions related to fruit traits has been described by other authors (Prohens et al., 2005; Özer et al., 2011; Tembe et al., 2020), confirming that morphological variation is strongest in the organ for which the crop was selected and expands during the growing process (Meyer & Purugganan, 2013). Considerable variation is found among landraces, in contrast to what is observed in commercial varieties, especially in F1 hybrids (Muñoz-Falcón et al., 2009).

To better understand the overall diversity of the 22 local Bulgarian eggplant populations, the data were analyzed by Cluster analysis that revealed the distribution of genetic diversity. In this study, cluster analysis grouped the populations into two clusters. The related dendogram is shown in Figure 5.

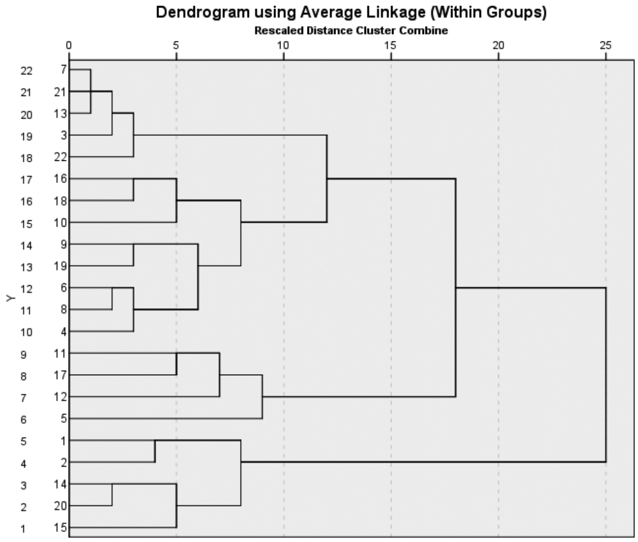

Fig. 5. Dendrogram showing the classification of 22 genotypes of local eggplant

In the first cluster group are accessions A7E0262, A7E0281, A7E0525, A8E0602 and A9E1416. They are characterized by an oval shape with violet to dark violet fruit color, 250–325 g weight, with light violet flowers. The second cluster includes all the other accessions, but we can separate a sub-cluster, including accessions B2E0303, A9E1431, A8E0552, A9E0537, in which the fruits are over 500 g.

This study showed that there is considerable morphological variability due to the introduction of different genetic materials in Bulgaria from different countries. The cluster groups were not related to the geographical origin of the eggplant genotypes. In studies by Turkish authors, it has been found that there are very significant morphological differences between local genetic resources of eggplant (Tümbilen et al., 2011).

Conclusions

Solanum melongena L. accessions, maintained in the collection in the National Genebank in IPGR – Sadovo, were characterized by basic morphological indices, applying multivariate techniques for phenotyping.

Plant fruit weight recorded a highly positive significant correlation with fruit width (r = 0.802**). Similarly, significant positive correlations were identified between days to flowering and fruit formation period (r = 0.867**) and between leaf length (r = 0.607**) leaf width (r = 0.593**) and crude protein.

The quality of fruit is considered most important and therefore total sugar, crude protein and dry matter content are determined. A9E1156, B2E0302, and A8E0531 being high in crude protein, A8E0604, B6E0332, and A9E0537 having lots of sugars while A7E0313, B4E0126, and A8E0586 were found to be high in dry matter.

Considerable diversity in the collection of local eggplant varieties was established. It is represented both in the morphological characters of the plants and size, shape, weight and color of the fruits.

The potential use of the local eggplant genetic resources as breeding material was described.

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