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PHENOTYPIC DIVERSITY OF BASIC CHARACTERISTICS OF GENOTYPES FROM THE SERBIA ONION COLLECTION

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The onion is a widely distributed vegetable crop, which takes an important place in the vegetable production in Serbia. The traditional planting method is the one from sets. Old cultivars and populations and, in recent years, foreign cultivars are grown. The large variety of genotypes, including both domestic populations and cultivars, comprises the significant gene pool of this region. The onion collection of the Institute of Field and Vegetable Crops in Novi Sad is based on the populations and cultivars from the territory of the former Yugoslavia. This paper reviews 30 onion genotypes on the basic IPGRI descriptors (ANNEX I). Variability of the reviewed characteristics was determined by PC analysis. High variability values have been established for bulb skin color, bulb flesh color, bulb hearting and bulb skin thickness. The genotypes varied in bulb skin color as well as in bulb flesh color from white to dark violet. These two characteristics had the largest impact on clustering, with a single genotype being heterogeneous exactly for these two characteristics.

Key words: hierarchical clustering, onion, PC analysis

INTRODUCTION

Onion is a monocot belonging to the family *Alliaceae* of the class *Liliopsida*, according to a classification by Takhtajan (FRITISCH and FRIESEN, 2002). Most authors (KAZAKOVA, 1978; FRITISCH and FRIESEN ,2002) cite central Asia as the primary center of this plant's origin and the Mediterranean as the secondary center of origin of large polyploid onion forms with brightly colored bulbs. A more detailed classification, made by KAZAKOVA (1978), divides onion into three subspecies. The basis of this classification is geographic origin and the related ecological factors (day length, temperature, moisture). Each of the subspecies comprises groups of cultivars with common biological and agronomic characteristics.

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Onion production in Serbia is carried out on an area of around 20,000 hectares, which is about 10% of the country's total acreage in vegetables (www.rzs.stat.gov.rs). Old varieties and populations are grown alongside an increasing number of foreign cultivars, which are slowly supplanting the former, resulting in genetic erosion (AGIČ et al. 2009). The most important reasons for such diversity of genotypes grown are the country's geographic position, the variety of agroclimatic conditions, and frequent large migrations of human populations with specific dietary habits (LAZIĆ *et al.* 1988).

In order to determine the genetic variability of onions grown in Serbia for the purposes of breeding, efforts are under way to preserve the existing gene pool consisting of old varieties and populations (ZDRAVKOVIĆ *et al.* 2009), collect the foreign genetic materials in use in the country, and compare the two sets to find differences and similarities among the onion accessions. The onion collection of the Institute of Field and Vegetable Crops in Novi Sad has as its basis domestic populations that have been in cultivation for an extended period of time and also contains foreign cultivars as well as lines obtained by breeding from the available gene pool. The objective of this paper was to analyze the main characteristics of the above-ground plant parts and bulbs of a number of our onion accessions of different origin.

MATERIALS AND METHODS

Thirty onion accessions of different origins were studied in the paper (Table 1.). Sixteen of them are populations and fourteen varieties. Twelve of the genotypes originate from Serbia (No 1-12), six each from Hungary (No 13-18) and Croatia (No 21-26), and two each from Macedonia (No 27 and 28), Bulgaria (No 29 and 30) and Slovenia (No 19 and 20). The ten basic plant characteristics from the "Descriptors for Allium spp."-Annex-I (IPGRI 2001) were studied: foliage color (7.1.1.), foliage attitude (7.1.5.), degree of leaf waxiness (7.1.8.), shape of mature dry bulbs (7.1.11.), population uniformity of bulb shape (7.1.14.), bulb skin color (7.1.15.), bulb skin thickness (7.1.17.), bulb flesh color (7.1.18.), bulb hearting (7.1.27.) and ability to flower (7.2.1.). All of the characters have been represented numerically. Trait variability analysis was performed by the PCA method, with the number of principal components being chosen based on the *scree* test (KOVAČIĆ, 1994). Ability to flower (7.2.1.) was not included in the PC analysis because all analyzed genotypes had the same value of that characteristic. Hierarchical cluster analysis was used to determine differences and similarities among the genotypes, and the distance measure used was Euclidean distance matrix, as the parameter that best reflects differences existing among the genotypes (KENDALL, 1980). Statistical analyses were performed using the Statistica program ver.9.1 (StatSoft, Inc., Tulsa, Oklahoma, USA).

RESULTS AND DISCUSSION

In the genotypes studied, foliage color ranged from green (3) to bluish green (7), with most of the genotypes having dark green (5) leaves (Table 1.). Foliage attitude was intermediate or erect. Erect leaves were found in Hungarian genotypes (Aroma, Teteny rubin, Favorit, Sonka hogma) and the domestic variety Alek. Such foliage attitude enables higher plant density, and these cultivars are also of the type that is grown from seeds. With the exception of the two genotypes from Bulgaria, Rekord-2 and Jubilej-50, all the genotypes studied in the paper were characterized by pronounced leaf waxiness.

Table 1. Characteristics of onion genotypes according to "Allium spp." descriptor

No	Collecting number	Characteristic									
		Foliage color	Foliage attitude	Degree of leaf waxiness	Shape of mature dry bulbs	Population uniformity of bulb shape	Bulb skin color	Bulb skin thickness	Bulb flesh color	Bulb hearting	Ability to flower
1.	Kol-NK-1	5	5	7	1	2	3	5	2	2	1
2.	Kol-NK-2	5	5	7	2	2	99	5	99	2	1
3.	Kupusin. jab.	5	5	7	5	1	4	5	1	1	1
4.	Alek	5	7	7	6	1	3	3	1	1	1
5.	Jasenički žuti	5	5	7	5	1	3	3	1	2	1
6.	Holandski žuti	5	5	7	1	1	3	5	1	2	1
7.	Kol-79	5	5	7	1	1	4	5	2	2	1
8.	Kol-129	5	5	7	8	2	8	5	4	1	1
9.	Kol-153	5	5	7	2	1	8	5	4	2	1
10.	Kol-154	5	5	7	2	1	3	5	2	2	1
11.	Kol-163	5	5	7	8	3	8	3	4	2	1
12.	Kol-166	5	5	7	2	1	3	5	2	2	1
13.	Makoi bronz	5	5	7	5	1	5	7	1	1	1
14.	Makoi feher	5	5	7	5	1	1	5	1	1	1
15.	Aroma	5	7	7	2	1	4	5	2	1	1
16.	Teteny rubin	5	7	7	5	1	9	3	4	1	1
17.	Favorit	5	7	7	5	1	4	5	2	1	1
18.	Sonka hogma	5	7	7	8	1	3	5	2	1	1
19.	Ptujski	5	5	7	2	2	9	5	4	2	1
20.	Belokrajanka	5	7	7	8	1	3	3	1	1	1
21.	Kol-51	5	5	7	3	2	8	5	4	2	1
22.	Kol-57	7	5	7	2	2	8	5	4	2	1
23.	Kol-58	3	5	7	3	2	8	5	4	2	1
24.	Kol-61	3	5	7	6	2	8	5	4	2	1
25.	Kol-62	7	5	7	2	2	9	3	4	2	1
26.	Kol-64	7	5	5	2	2	8	3	4	2	1
27.	Kol-66	5	5	7	3	2	4	5	2	2	1
28.	Kol-67	7	5	7	2	2	4	5	2	2	1
29.	Rekord-2	5	5	5	3	1	3	5	1	1	1
30.	Jubilej-50	3	5	3	5	1	2	5	1	1	1

*__7.1.1__. Foliage color (1-light green; 2-yellow green; 3-green; 4-grey-green; 5-dark green; 6-bluish green; 7-purplish-green; 99-other); **7.1.5.** Foliage attitude (3-prostrate ; 5-intermediate; 7-erect); **7.1.8**. Degree of leaf waxiness (3-weak; 5-medium; 7-strong); **7.1.11**. Shape of mature dry bulbs (1-flat; 2-flat globe; 3-rhomboid; 4 -broad oval; 5-globe; 6-broad elliptic; 7-ovate-elongated oval; 8-spindle; 9-high top; 99-other); **7.1.14**. Population uniformity of bulb shape (1-uniform –homogeneous; 2-variable; 3-highly variable); **7.1.15.** Bulb skin color (1-white; 2-yellow; 3-yellow and light brown; 4-light brown; 5-brown; 6-dark brown; 7-green, chartrese; 8-light violet; 9-dark violet; 99-other); **7.1.17**. Bulb skin thickness (3-thin; 5-medium; 7-thick); **7.1.18**. Bulb flesh color (2-cream; 3-green/white; 4-violet/white; 99-other); **7.1.27**. Bulb hearting (1-single heart; 2-2-3 hearts; 3-more than 3 herts); **7.2.1**. Ability to flower (0-No; 1-Yes)

Bulb shape was flat (1) to spindle (8). Flat to flat globe bulbs were found in domestic populations (Kol-NK-1; Kol-NK-2; Kol-79; Kol-153; Kol-154; Kol-166; Kol-57; Kol-62; Kol-64, Kol-67), which originated from Serbia, Croatia and Macedonia, grown from seeds sets (GVOZDANOVIĆ-VARGA *et al*. 2005), which is the traditional way of growing onions in this region (ĆOTA *et al.* 2012). By force of habit, consumers in Serbia still prefer flat bulbs with light brown or yellow skin color and distinctly white flesh color that store well and taste good. Elongated violet bulbs are typical of genotypes intended for fresh consumption, which are most commonly produced from seed sets and have a distinctive taste. (GVOZDANOVIĆ-VARGA *et al*. 1996). The populations from Croatia (Kol-51 to Kol-64) had light violet (8) to dark violet (9) bulbs, but their shape varied from flat globe (2) to broad elliptic (Kol-61). High variability in bulb color and shape was also observed in cultivars from Hungary. The cultivar Makoi feher had white (1), globe shaped (5) bulbs. The cultivar Teteny rubin had violet bulbs (9), the cultivar Sonka hogma yellow to light brown bulbs (3) (Tab.1). Population uniformity of bulb shape was not very high. Still, it may be said that, in general, the cultivar were homogeneous in bulb shape while the populations were variable (2). Bulb color ranged from white (Makoi feher) to dark violet (Teteny rubin, Ptujski, Kol-62).

Figure 1. Bulb from Kol-NK-2

Kol-NK-2 was very heterogeneous regarding bulb color (Fig. 1.). Bulb skin thickness was medium (5) in most of the examined genotypes. The cultivar Makoi bronz was an exception with its thick (7) skin (Tab. 1). Bulb hearting was found to be negatively correlated with bulb shape (GVOZDANOVIĆ-VARGA *et al.* 1996a); the genotypes with globe-, broad elliptic- and spindle-shaped bulbs, i.e. the cultivars and one population (Kol-129), typically had a single heart.

Trait variability was represented with four principal components, which explained 78.58% of total variability. The first two PCs were similar in importance (25.74 and 22.67%, respectively) and they comprised about a half of the variability existing in the analyzed collection (Tab. 2) (RAAMSDONK, VRIES 1992). The first component incorporated uniformity of

bulb shape and bulb hearting, which were highly interdependent (GVOZDANOVIĆ-VARGA *et al.* 1996a), as well as foliage attitude, which was negatively correlated with the said two traits. The second PC included the color characteristics (bulb skin color and bulb flesh color). The high percentage of PC2 in the total variability resulted from phenotypic differences of the bulb among the genotypes. The third and fourth PCs included leaf characteristics, bulb skin thickness, foliage color and degree of leaf waxiness (Tab. 2).

Table 2. Principal component analysis of onion traits studied

Characteristic	*PC 1*	*PC 2*	*PC 3*	*PC 4*
Foliage color (7.1.1.)	0.226	-0.093	-0.186	**0.724**
Foliage attitude (7.1.5.)	**-0.844**	-0.019	-0.273	0.223
Degree of leaf waxiness (7.1.8.)	-0.097	0.131	0.029	**0.723**
Shape of mature dry bulbs (7.1.11.)	-0.546	-0.044	-0.563	-0.361
Population uniformity of bulb shape (7.1.14.)	0.696	0.227	-0.463	0.017
Bulb skin color (7.1.15.)	0.118	**0.985**	0.023	0.044
Bulb skin thickness (7.1.17.)	0.034	0.070	**0.852**	-0.191
Bulb flesh color (7.1.18.)	0.090	**0.986**	0.038	0.029
Bulb hearting (7.1.27.)	**0.859**	0.113	0.025	0.282
Latent Roots (Eigenvalues)	2.787	1.717	1.487	1.082
Percent of total variance explained	**25.74**	**22.67**	**15.21**	**14.96**
Cumulative variation (%)	25.74	48.41	63.62	**78.58**

Clustering of traits was made in order to visually present their individual contribution to the similarities and differences in the onion collection. The traits were separated into two groups (Figure 2). The first one included leaf features, foliage color (7.1.1.) and foliage attitude (7.1.5.). The second one included bulb features, bulb hearting (1.7.27.) and population uniformity of bulb shape (1.7.14.). The first group is important for identification of phenotypic differences already during the growing season, because these traits are positively correlated with yield (HAYDAR *et al.* 2007), which is an important information for breeders. The second group pertains in the first place to the heterogeneity of bulbs within the genotype, and thus to their heterogeneity within the collection. MCCALLUM *et al*. (2001) stated that high heterogeneity of genotypes is desirable since it provides greater opportunities to the breeder to select advantageous traits defined by plant model.

The primary separation of the genotypes into clusters was done based on traits with the most variability, i.e. those forming part of the first two components. The assessed genotypes were divided in two groups and three genotypes which were outside of these groups (Fig. 3.) The first group included genotypes with dark-colored bulbs, from dark brown to violet. Bulb shape was flat to rhomboid. The first group consisted of six populations and a single cultivar (Ptujski). The second group was more numerous than the first one. It included 18 genotypes. Although they differed in bulb color from white (1) to brown (5), most of them were yellow and light brown (3). The bulbs were flat to spindle-shaped. This group too included six populations. The rest were selected cultivars of different origin.

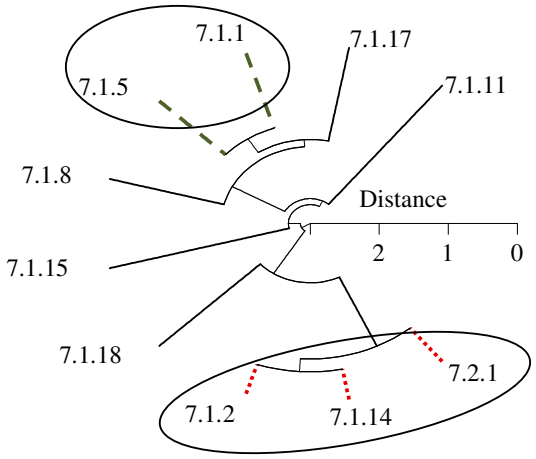

Fig. 2. Hierarchical classification of onion traits studied; **7.1.1**. Foliage color; **7.1.8**. Degree of leaf waxiness; **7.1.11**. Shape of mature dry bulbs; **7.1.14**. Population uniformity of bulb shape; **7.1.15.** Bulb skin color; **7.1.17**. Bulb skin thickness; **7.1.18**. Bulb flesh color; **7.1.27**. Bulb hearting; **7.2.1**. Ability to flower.

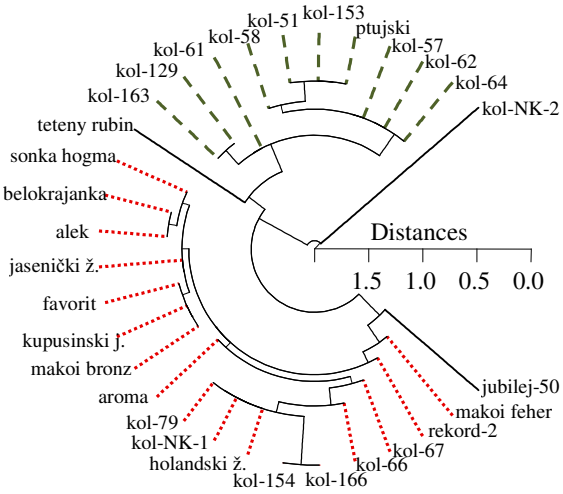

Fig. 3. Hierarchical classification of onion collection material

The population Kol-NK-2 stood apart by virtue of its heterogeneity for bulb color and bulb flesh color and shape and was at the greatest distance from the two clusters. These characteristics placed this population at the top of the hierarchy, while the Bulgarian cultivar Jubilej-50 was at the bottom of the dendrogram. The Hungarian cultivar Teteny rubin too did not belong to any group although it was associated with the first group on account of similarities in bulb characteristics, i.e. color of dry leaves and flesh.

CONCLUSION

Analysis of the main characteristics of the onions from our collection revealed phenotypic differences for the characters of the above-ground plant parts and the bulb. Heterogeneity for bulb color and shape was used to separate the populations and cultivars into two groups, indicating the importance and desirability of the collection materials studied for onion breeding purposes.

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FENOTIPSKE RAZLIKE U OSNOVNIM KARAKTERISTIKAMA KOLEKCIJE GENOTIPOVA CRNOG LUKA IZ SRBIJE

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Izvod

Crni luk je široko rasprostrnjena povrtarska vrsta, čija proizvodnja zauzima značajno mesto u setvenoj strukturi povrća u Srbiji. Tradicionalni način ove proizvodnje je iz arpadžika, gde su zastupljene stare sorte, populacije i sve prisutniji strani sortiment. Bogatstvo genotipova crnog luka, kako gajenih domaćih populacija tako i sorata, predstavlja značajan gen fond sa ovog područja. U Institutu za ratarstvo i povrtarstvo u Novom Sadu, osnovu kolekcije čine domaće populacije i sorte koje se gaje u širem region, sa prostora bivše Jugoslavije. U radu su prikazane osnovne osobine 30 genotipova crnog luka prema deskriptoru IPGRI (ANNEX I.). Varijabilnost ispitivanih osobina je utvđena PC analizom, gde je ustnovljena visoka varijabilnost za boju lukovice, boju sočnih listova lukovice, broj gnezda i debljinu listova lukovice. Genotipovi su imali boju lukovice od bele do tamno ljubičaste, a takođe i boja sočnih listova. Ove dve osobine su imale najveći uticaj na grupisanje genotipova, tako su formirane dve grupe, uz izdvajanje jednog genotipa koji je heterogen upravo za ove osobine.

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