Preliminary communication
Претходно саопштење
UDC 635.25:575.22(497.4)
DOI 10.7251/AGREN2304237S

University of Banjaluka, Faculty of Agriculture
Agro-knowledge Journal

Morphological diversity of onion genetic resources at the Agricultural Institute of Slovenia

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Abstract

Onion is an important vegetable crop grown for its pungent bulbs and aromatic leaves. Onion genetic resources collected in the Slovenian Plant Gene Bank at the Agricultural Institute of Slovenia were evaluated for the first time using various morphometric traits. Using the prescribed descriptors (UPOV, CPVO) for *Allium cepa* spp., a collection of 61 onion accessions and varieties grown in the experimental fields of the Infrastructure Centre Jablje in 2022 was described. For each onion genetic resource, a total of thirteen quantitative (numerical) and qualitative descriptors were evaluated on the bulbs: bulb size, bulb height, bulb diameter, ratio height/diameter, position of maximum diameter, width of the neck, shape in longitudinal section, shape of stem end, shape of root end, base colour of dry skin, intensity of base colour of dry skin, coloration of epidermis of fleshy scales, and dry matter content. The results showed significant differences between onions in the collection in terms of bulb size (73.7 ± 26.0 g), bulb height (46.3 ± 14.2 mm), bulb diameter (36.7 ± 6.8 mm), bulb shape (predominant transverse medium elliptic), and colour of dry skin (brown, pink, red, purple). The highest coefficients of variation were observed for bulb size (35.3%) and height/ diameter ratio (32.6%) and the lowest for dry matter content (8.6%). The data obtained and the variability of the traits studied indicate that these onion accessions require further genetic analysis to identify the best candidates for future breeding programmes.

Key words: accession, *Allium cepa*, CPVO, descriptors, dry matter, UPOV.

Introduction

Onions (*Allium cepa* L. var. *cepa*) are among the most important members of the *Allium* genus and are widely cultivated and used throughout the world (Manjunathagowda et al., 2021; Zhao et al., 2021). They are mainly cultivated for the bulb, which consists of fleshy inner scales and dry outer scales. Depending on the colour of the outer leaves, three main types of onions can be distinguished, namely red, yellow/ brown, and white onions (Naqash et al., 2022). In Slovenia, onion cultivation is widespread, both in small gardens and for market production. Annual production reached 10,514 tons of onions on 441 ha in 2021, of which 74% was destined for the market (Republic of Slovenia Statistical Office [SI-STAT], 2022). The average onion yield depends mainly on weather conditions and cultivation technique and is 20 – 30 tons/ha. The quantities of onions produced are encouraging compared to previous years, but they are far from meeting the needs of the market. In 2021, as much as 14,196 tons of onions were imported, mainly from Austria and the Netherlands, and domestic production met only about 40% of market demand (SI-STAT, 2022). In the past, onion production provided additional income to many small farms, as evidenced by some old onion varieties from different Slovenian regions (Ptujsko polje, Bela Krajina, Dolenjska). Currently, six onion varieties are registered in the Slovenian Variety List, namely 'Holandska rumena', 'Račanka', 'Belokranjka', 'Ptujska rdeča', 'Tera' and 'Ivica rdeča' (National List of Varieties, 2022).

The International Union for the Protection of New Varieties of Plants (UPOV) (2008) and the Community Plant Variety Office (CPVO) (2009) coordinate methods and establish guidelines for the description of onion varieties/ genetic resources. The purpose of the guidelines is the coordinated observation and evaluation of morphological-phenological parameters according to the onion descriptors used for DUS testing (distinctness, uniformity, and stability). By evaluating morphometric descriptors such as length, width, height, shape, or colour, it is possible to distinguish within or between plant species, and such descriptors serve as basic databases for breeders and researchers. Each descriptor has a prescribed method of description, which can be represented by a sketch, a number, or a description (UPOV, 2008; CPVO, 2009).

The diversity of plant genetic resources in gene banks around the world is the basis for plant breeding. The task of gene banks is their conservation, study, collection, identification of genetic diversity, and prevention of genetic erosion (Gomaa, 2012; Peres, 2016). In Slovenia, native populations, ecotypes, and local varieties of important crops have been collected for a long time. At the Agricultural Institute of Slovenia, genetic resources of various agricultural crops are collected within the Slovenian Plant Gene Bank programme, including genetic resources of onions. So far, these have not been evaluated using

morphometric descriptors, so in the research work a description of the onion collection was made using selected descriptors. A set of descriptors from UPOV (2008) and CPVO (2009) defined in the guidelines for the evaluation of genetic resources of *Allium cepa* spp. was used.

Material and Methods

The considered collection included a total of 61 onion genetic resources (*Allium cepa* L. var. *cepa*), of which 58 accessions were acquired from the Slovenian Plant Gene Bank (SRGB) of the Agricultural Institute of Slovenia and three varieties ('Ptujska rdeča' and 'Hollandska rumena' – Semenarna Ljubljana, 'Talon' – Agrocasol Plus) were purchased from seed suppliers. The production of seedlings and the field trial took place on the experimental fields of the Infrastructure Centre Jablje in 2022. Due to the limited amount of seed of the accessions from the SRGB, a trial was established with ten plants from each onion genetic resource. Seedlings were grown in polystyrene plates (160 cells) in a heated greenhouse. Seeds were sown in late February (23 February 2022), seedlings were planted in the field in mid-April (13 April 2022), and mature bulbs were harvested in late July (26 July 2022). The seedlings were planted in the field in four-row strips 30 cm × 10 cm apart and a drip irrigation system was installed. When the soil was prepared, it was fertilized with 120 kg/ha of K2O according to the analysis, while 28 kg/ha of N was added before planting. The onion plants were fertilized once during growth with 54 kg/ha N and irrigated when necessary. The onions were harvested at the stage of technological maturity and dried in a dry, dark place for several weeks. Morphological characterization was performed on cleaned, fully developed bulbs of each onion genetic resource.

A set of thirteen descriptors prescribed by UPOV (2008) and CPVO (2009) for onion bulbs was used to describe the onion genetic resources in the collection. The following descriptors were determined on five individual bulbs of each onion genetic resource: bulb size (g), bulb height (mm), bulb diameter (mm), ratio height/ diameter, position of maximum diameter, width of the neck (mm), shape in longitudinal section, shape of stem end, shape of root end, base colour of dry skin, intensity of base colour of dry skin, coloration of epidermis of fleshy scales, and dry matter content (°Brix). These descriptors, along with their associated classes, are shown in Tab. 1. The numerical parameters bulb height (mm), bulb diameter (mm), and width of the neck (mm) were measured with a digital calliper (Mitutoyo 500-181-30) with an accuracy of 0.1 mm, while the dry weight of the bulbs (g) was measured with a laboratory scale (PB1502, Mettler Toledo) with an accuracy of 0.01 g. A portable digital refractometer (WZB-F35, Sumer Instrument, Thermo Shaker) was used to determine dry matter content (°Brix) by squeezing small pieces of the fleshy inner scales with a press and

analysing the freshly squeezed onion juice in three replicates. All numerical descriptors were also evaluated by the corresponding classes marked with a number, as in Tab. 1.

Tab. 1. Set of thirteen qualitative-quantitative descriptors for bulbs with associated classes evaluated on the onions in the collection

CPVO/UPOV descriptor	Bulb	Class
12.1 (g)	Size	3 small, 5 medium, 7 large
13.1 (mm)	Height	1 very short, 3 short, 5 medium, 7 tall, 9 very tall
14.1 (mm)	Diameter	3 small, 5 medium, 7 large
15.1	Ratio height/diameter	1 very small, 3 small, 5 medium, 7 large, 9 very large
16.	Position of maximum diameter	1 towards stem end, 2 at middle, 3 towards root end
17. (mm)	Width of the neck	1 very narrow, 3 narrow, 5 medium, 7 broad, 9 very broad
18.	Shape in longitudinal section	1 elliptic, 2 medium ovate, 3 broad elliptic, circular, 4 broad ovate, 5 broad obovate, 6 rhombic, 7 transverse medium elliptic, 8 transverse narrow elliptic
19.	Shape of stem end	1 depressed, 2 flat, 3 slightly raised, 4 rounded, 5 slightly sloping, 6 strongly sloping
20.	Shape of root end	1 depressed, 2 flat, 3 round, 4 weakly tapered, 5 strongly tapered
23.	Base colour of dry skin	1 white, 2 grey, 3 green, 4 yellow, 5 brown, 6 pink, 7 red, 8 purple - *additional*
24.	Intensity of base colour of dry skin	3 light, 5 medium, 7 dark
26.	Coloration of epidermis of fleshy scales	1 absent, 2 greenish, 3 reddish
28. (°Brix)	Dry matter content	1 very low, 3 low, 5 medium, 7 high, 9 very high

Results and Discussion

The use of quantitative (numerical) and qualitative descriptors for the study and evaluation of onion genetic resources has been the subject of many studies worldwide (Bağci et al., 2022; Petropoulos et al., 2015; Mallor et al., 2011). Onion breeders mainly focus on onion bulb characteristics such as colour, shape, soluble solids content, pungency and flavour, storability, and health-promoting properties (Havey, 2018). Tab. 2 summarises the results of statistical processing of numerical descriptor measurements for 61 onion genetic resources

in the collection. The mean dry weight of onion bulbs in the collection was 74 g, while bulb height and diameter were 46 mm and 56 mm, respectively. The average ratio height/ diameter in the onion collection was 0.84 and the average width of the neck was 14 mm. The range between the smallest (minimum) and largest (maximum) dry weight of bulbs was from 22.87 g to 143.28 g, bulb height from 33 mm to 100 mm, and bulb diameter from 37 mm to 69 mm. The dry matter content of freshly pressed onion juice varied from 6.7 °Brix to 13.5 °Brix. The highest coefficient of variation was found for bulb size (35.51%) and height/ diameter ratio (32.57%), and the lowest for dry matter content (8.58%).

Bağci et al. (2022) reported slightly higher dry weight of bulbs in red onion genotypes, while the values for bulb height, bulb diameter, and width of the neck were consistent with our data. Similarly, Petropoulos et al. (2015) reported slightly higher dry weight of bulbs (>120 g) and bulb diameters (>60 mm) for local onion genetic resources in Greece. Characterization of 86 onion genetic resources in Spain revealed significantly higher dry weight of bulbs (245±125 g) and coefficient of variation (51%) compared to our data (Mallor et al., 2011).

Tab. 2. Numerical descriptors on bulbs in the collection of 61 onion genetic resources

Parameter	Unit	Min - Max	Mean ± SD	CV (%)
Bulb size	g	22,87 – 143,28	73,72 ± 26,03	35,31
Bulb height	mm	32,77 – 99,60	46,28 ± 14,22	30,72
Bulb diameter	mm	36,67 – 69,40	56,04 ± 6,81	12,15
Ratio height/diameter		0,62 – 2,03	0,84 ± 0,27	32,57
Width of the neck	mm	8,70 – 19,68	13,52 ± 2,21	16,37
Dry matter content	°Brix	6,74 – 13,53	11,94 ± 1,02	8,58

n=61; SD, standard deviation; CV, coefficient of variation.

Based on the descriptor bulb size (dry weight of bulb), the onion collection was divided into three groups (Fig. 1a). The first group included genetic resources with small bulbs weighing <60 g (34% of the collection), the second group included onion genetic resources with medium bulbs weighing 60 g to 90 g (41% of the collection), and the third group included onion genetic resources with large bulbs weighing >90 g (25% of the collection). According to the descriptor bulb height (Fig. 1b), most onion genetic resources in the collection belonged to the low (49% of the collection) or very low (33% of the collection) class. Based on the bulb diameter, onion genetic resources in the collection can also be divided into three groups (Fig. 1c). The first group included 21 genetic resources with small bulb diameter <55 mm, the second group included 25 onion genetic resources with bulb diameter from 55 mm to 65 mm, and the third group included 15 onion genetic resources with a large bulb diameter >65 mm. The width of the neck was narrow (11 – 13 mm) or medium (13 – 15 mm) in most of the onion genetic resources in the collection (Fig. 1d).

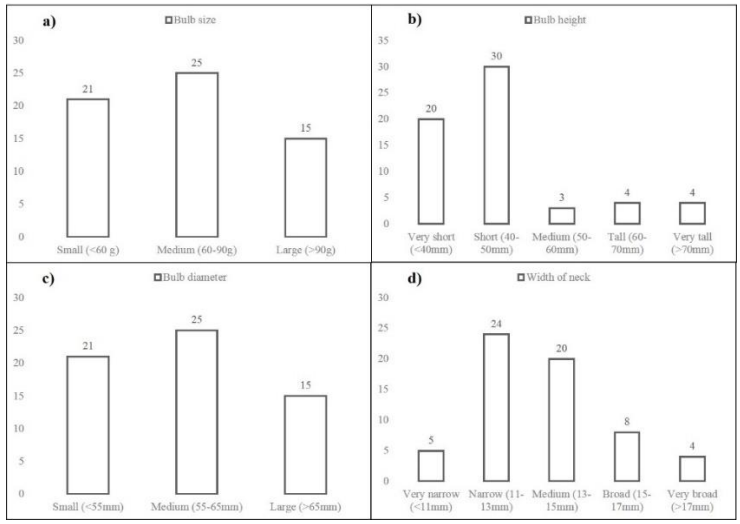

Figure 1. Frequency distribution (n=61) of the onions in the collection based on a) bulb size, b) bulb height, c) bulb diameter and d) width of the neck

Fig. 2 shows the distribution of onion genetic resources in the collection based on two descriptive traits, i.e. the base colour of dry skin (Fig. 2a) and the intensity of base colour of dry skin (Fig. 2b). The studied onions in the collection had different numbers of basic dry skin colours: 17 onion genetic resources had one colour (brown or purple), 20 onion genetic resources had two colours (pink/ purple, red/ purple, or brown/ pink), and 24 onion genetic resources had three colours (brown/ pink/ purple). In general, the dry skin of onion bulbs in the collection was brown, pink, red, and/or purple. The intensity of the base colour was medium or light for the majority of onion genetic resources in the collection (Fig. 2b).

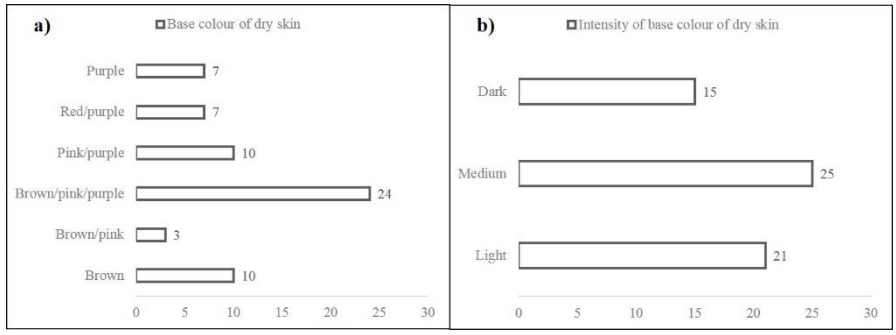

Figure 2. Frequency distribution (n=61) of the onions in the collection based on a) base colour and b) intensity of base colour of dry skin

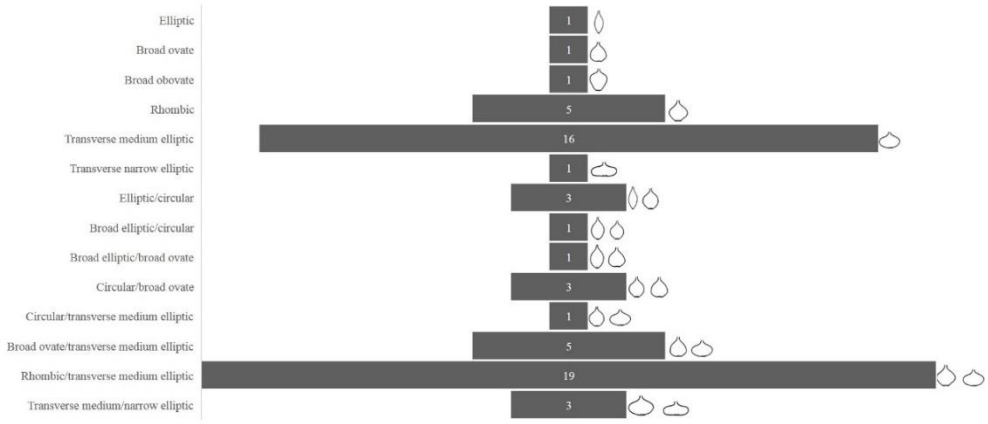

Figure 3. Frequency distribution (n=61) of the onions in the collection based on bulb shape

Fig. 3 shows the distribution of the onions in the collection by a bulb shape. The most represented bulb shapes in the onion collection were rhombic/ transverse medium elliptical (19 genetic resources) and transverse medium elliptical (16 genetic resources). 59% of the collection, or 36 onion genetic resources, had two different bulb shapes, generally due to the lower uniformity and homogeneity of accessions from gene banks compared to registered varieties.

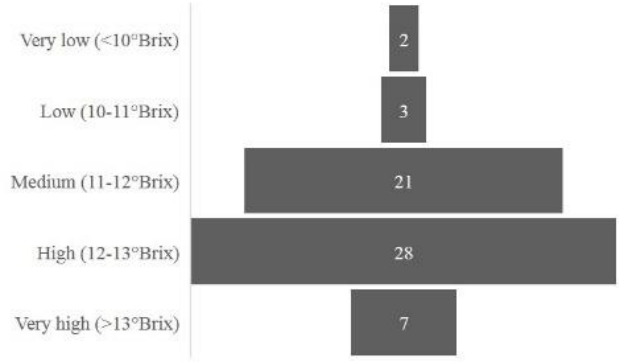

Figure 4. Frequency distribution (n=61) of the onions in the collection based on dry mater content

Fig. 4 shows the distribution of the onions in the collection based on dry matter content. For most of the onion genetic resources in the collection, 49 in total, dry matter content was medium or high, ranging from 11 °Brix to 13 °Brix.

Two onion genetic resources had very low dry matter content (<10 °Brix), while in seven onion genetic resources it was very high (>13 °Brix). Golubkina et al. (2022) reported much lower dry matter contents (6.6 – 8.2 °Brix) in 11 onion varieties grown organically and conventionally in southern Italy. The onion genetic resources from Spain also had lower dry matter content (average 8.8 °Brix) than our data (Mallor et al., 2011), while the Greek onion genotypes ranged from 10.0 °Brix to 14.0 °Brix (Petropoulos et al. 2015).

Conclusion

Based on the results obtained, the following conclusions can be drawn: (i) the onion accessions from the SRGB of the Agricultural Institute of Slovenia had a relatively high morphological diversity based on the UPOV/CPVO descriptors studied; (ii) a minority of the onion collection had outer dry scales coloured brown or purple, while the majority had a colour mixture of brown, pink and/or purple; (iii) 21 onion genetic resources developed small onion bulbs (<60 g), 25 medium (60 – 90 g) and 15 large onion bulbs (>90 g); (iv) the predominant shape of onion bulbs in the collection was rhombic/ transverse medium elliptical; (v) the onion collection represents a diverse heritage that can play a key role in the breeding of new onion varieties in Slovenia and prevent genetic erosion in the future.

Acknowledgement

This study was funded by the research programme Agrobiodiversity (P4-0072), financed by the Slovenian Research Agency. The authors would like to thank the national coordinator of the Slovenian Plant Gene Bank (SRGB), Dr. Jelka Šuštar Vozlič, for facilitating the evaluation of material from the gene bank, and the project PRP (No. 430-122/2020), under which the field trial was designed.

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Морфолошки диверзитет генетичких ресурса црвеног лука у Пољопривредном институту Словеније

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Сажетак

Црвени лук је важна повртарска врста која се узгаја због луковица и листова оштрог укуса и ароматичног мириса. Генетички ресурси црвеног лука прикупљени у Словеначкој банци биљних гена на Пољопривредном институту Словеније сада су први пут процијењени на основу различитих морфометријских својстава. Примјеном прописаних дескриптора (UPOV, CPVO) за *Allium cepa* spp. описана је колекција од 61 принове и сорте црвеног лука које су произведене на огледним пољима Инфраструктурног центра Јабље током 2022. године. За генетичке ресурсе црвеног лука урађено је укупно тринаест квантитативних (нумеричких) и квалитативних особина на луковицама: величина луковице, висина луковице, пречник луковице, однос висина/пречник, положај највећег пречника, ширина врата луковице, облик у уздужном пресјеку луковице, облик горњег дијела (врха) луковице, облик доњег дијела (базе) луковице, основна боја сувих овојних листова, интензитет основне боје сувих овојних листова, обојеност покожице сочних листова и садржај суве материје. Резултати су показали значајне разлике између принова црвеног лука у колекцији у погледу величине луковице (73,7±26,0 г), висине луковице (46,3±14,2 мм), пречника луковице (36,7±6,8 мм), облика луковице (претежно попречно средње елиптичан) и боје сувих овојних листова (смеђа, ружичаста, црвена, љубичаста). Највећи коефицијенти варијације забиљежени су за величину луковице (35,3%) и однос висина/пречник (32,6%), а најмањи за садржај суве материје (8,6%). Добијени подаци и варијабилност проучаваних својстава показују да ови узорци лука захтијевају даљу генетичку анализу како би се идентификовали најбољи кандидати за будуће оплемењивачке програме.

Кључне ријечи: принова, *Allium cepa*, CPVO, дескриптори, сува материја, UPOV

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Received: March 06, 2023
Accepted: August 30, 2023