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Characterisation of local population of spring garlic (*Allium sativum* L.) from Ljubinje, Republic of Srpska

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Abstract

Genetic resources such as garlic (*Allium sativum* L.) play a crucial role in the preservation of agricultural biodiversity, food security and breeding programs aimed at improving yield and resilience. Garlic is a vegetatively propagated crop with strong site-specific adaptation that often loses its typical morphological characteristics when transferred to a different agroecological zone. For the specified reasons, the aim of this study was to analyse the local population of spring garlic, which is of particular importance for the area of East Herzegovina, locally called Saransak, which is an important genetic resource as well. The results indicated an average bulb weight of 40.42 g, with an average of 15.30 cloves per bulb and 6.63 dry external scales. The bulb dimensions were 42.69 mm in height and 43.93 mm in diameter, whereas the clove characteristics included an average weight of 3.28 g, height of 36.14 mm and diameter of 13.71 mm. Additionally, the soluble dry matter content was 15.73% Brix, suggesting a high nutritional potential and marketability. These morphological traits align with previous studies that have highlighted bulb weight and clove number as critical factors for improving garlic yield and quality. The high bulb weight and clove count suggest that Saransak could be a promising candidate for breeding programs aimed at enhancing commercial garlic varieties. Furthermore, the observed morphological variability underscores the adaptive traits of garlic and the influence of environmental conditions on phenotypic expression. This study provides valuable insights into the genetic resources of garlic and supports future breeding efforts to develop high yielding and environmentally resilient varieties. Given its favorable agronomic characteristics, the Saransak population warrants further research for its potential application in garlic cultivation and improvement.

Key words: genetic resource, bulb, clove, morphology, soluble dry matter

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INTRODUCTION

Plant genetic resources play a crucial role in agricultural sustainability by supporting conservation efforts and crop adaptation to changing environmental conditions (Todorović et al., 2013). The study of genetic variability in crops is essential to maintain biodiversity and ensure long-term productivity. Garlic (*Allium sativum* L.) is an important crop that exhibits significant morphological diversity and is essential for maintaining adaptability and resilience. Owing to their long history of cultivation and selection, numerous landraces have developed, each adapted to specific climatic and soil conditions (Casals et al., 2023). Unlike sexually reproducing crops, garlic propagates vegetatively, resulting in genetic stability of its quantitative and qualitative traits, which is expressed as phenotypic uniformity across different environments (Janick, 1999).

Garlic is characterized by a wide range of morphological traits that influence its growth, yield, and quality. Key characteristics, such as bulb weight, number of cloves, bulb height and bulb diameter, are interrelated and significantly affect overall productivity. For instance, bulb weight positively correlates with bulb diameter and the number of cloves per bulb, meaning that larger bulbs generally contain more cloves and have a greater overall weight (Dixit et al., 2023; Santos et al., 2022). Additionally, bulb diameter is an essential quality parameter, because larger bulbs are often associated with better market acceptance and higher commercial value (Lima et al., 2020; Aziz, 2024). In addition to yield-related traits, morphological variations in garlic also influence its culinary and medicinal properties. Differences in bulb size, shape and colour are linked to variations in flavour, nutrient composition and storage potential (Jia et al., 2023; Shemesh-Mayer, 2023). Dry soluble matter content, commonly measured as % Brix, is another critical quality parameter, with higher values indicating better flavour and improved storage quality (Atif et al., 2020; Shaban et al., 2019). This trait is affected by genetic factors, environmental conditions and cultivation practices (Goyal et al., 2022; Dawa et al., 2012). Integrating morphological assessments with molecular techniques provides a comprehensive approach to understanding the genetic diversity of garlic.

Given the significance of garlic as both a food and medicinal crop, studying its morphological characteristics enhances conservation strategies and optimizes cultivation practices under diverse conditions (Benke et al., 2021; Egea et al., 2017; Cunha et al., 2014). Characterizing local garlic populations allows researchers to identify unique genotypes with valuable traits, contributing to the sustainable development of garlic production and the preservation of genetic resources. Therefore, the aim of this study was to evaluate and characterize a local spring garlic (*Allium sativum* L.) population, as it has been shown to be of particular importance for Eastern Herzegovina and has great potential for use in commercial and organized production. Additionally, this study aimed to assess the morphological and agronomic diversity of this population and identify key traits that influence yield, quality and adaptability.

MATERIAL AND METHODS

The experiment was conducted in 2024 on the spring garlic population 'Saransak', cultivated in an open field in Ubosko, a village near Ljubinje (43°01'04’’N, 18°04'21’’E, altitude 420 m). The planting was conducted in the first decade of February at a spacing of 20 × 20 cm, while the garlic harvest took place in the first decade of July. After harvesting, the bulbs were stored at a temperature of about 10°C. A randomized block design was employed for the experimental setup.

Measurements of physiologically mature bulbs included bulb weight (g), number of cloves, number of dry external scales, bulb height (mm), bulb diameter (mm), clove weight (g), clove height (mm) and clove diameter (mm). These measurements were taken at the Seed Laboratory of the Institute for Genetic Resources (UNIBL) of the Republic of Srpska, while the soluble dry matter content (TSS) (% Brix) was analysed at the Laboratory for Pomology and Biotechnology at the same institute.

International Plant Genetic Resources Institute – IPGRI (2001) descriptors for garlic were used to characterize the vegetative parts of the plant. IPGRI descriptors are crucial for standardizing the characterization of garlic germplasm, ensuring consistency in documenting morphological, agronomic and biochemical traits. Colorimetric analyses were performed using a WR18/4-8 (FRU) colorimeter. Graphic representations were created by inputting the colorimetric values a^*, b^* and L^* into the Lab tool option of the CorelDRAW X8 program and converting them into the closest standard colour values. The soluble dry matter content in the cell sap (% Brix) was measured using a HANNA Instruments Refractometer HI96801 with a measurement range of 0-85% Brix. Bulb and clove weights were determined using a WANT Electronic Balance FA2004GM with a readability of 0,01 g. The bulb and clove dimensions were measured using a UNIOR Digital Caliper 270A.

Data analysis involved descriptive statistics, where the arithmetic mean, standard deviation and coefficient of variation (CV, %) were calculated. The data were processed using Microsoft Office Excel 2016 and are presented as tables and figures.

Figure 1. Saransak production locality (left), storage (centre) and measuring (right) (original of the author)

RESULTS AND DISCUSSION

Conducting an IPGRI description of a plant is essential for the standardized characterization, conservation and utilization of genetic resources. This approach ensured consistent data collection, allowing researchers to compare plant traits across studies and locations. IPGRI descriptors play a key role in identifying unique genetic traits, supporting breeding programs, biodiversity conservation and sustainable agriculture (IPGRI, 2001). In this context, the Saransak garlic population, an autochthonous spring-type garlic, was previously inventoried in the Gene Bank of the Institute for Genetic Resources at UNIBL. Earlier analyses have been conducted on a population maintained by a local producer, highlighting its importance as a valuable genetic resource. Given its current presence in local gardens, the morphological traits of Saransak garlic are particularly significant for potential commercial production. Standardized descriptions of such varieties not only aid in germplasm evaluation, selection and exchange, but also contribute to the development of climate-resilient crops and the preservation of local landraces and wild relatives for future breeding efforts (Ochar & Kim, 2023).

The results in Tab. 1. indicated that the autochthonous garlic population Saransak from the Ljubinje region exhibits a compact, globular to slightly oblate bulb shape with a well-developed fibrous root system at the basal plate, ensuring efficient nutrient uptake and strong anchorage. The cloves were arranged in a radial pattern around the central axis, varying in size but consistently elongated and slightly curved, with a broad base and tapering apical end. Each clove is enveloped in a thin, dry external scale, ranging from white to light beige, which provides essential protection against desiccation and mechanical damage. The internal structure of the cloves revealed a firm, parenchymatous storage tissue rich in fructans, which is crucial for energy storage and drought resistance. Additionally, the presence of embryonic buds at the apical ends of cloves highlights the strong vegetative propagation potential of this garlic population. Research has indicated that the dormancy of garlic cloves can be effectively broken by exposure to low temperatures. For instance, Desta et al. (2022) demonstrated that garlic cloves subjected to cold storage at temperatures of 5°C or 10°C for 15 to 30 days exhibited accelerated maturity and earlier emergence than those stored at higher temperatures. This chilling treatment enhances the physiological readiness of cloves, allowing them to transition to active growth more efficiently. The physiological mechanisms underlying this transition involve various biochemical changes, including mobilization of carbohydrates and enzymes that support sprouting and growth (Mashayekhi et al., 2015). The compact bulb structure and protective tunics contribute to extended shelf life and post-harvest stability, making them suitable for broader market distribution. The adaptation of this variety to local agroecological conditions indicates its potential for organic and sustainable cultivation, which could enhance its economic value. Furthermore, its genetic stability and unique characteristics make it a promising candidate for branding as a regional specialty product (Moravcevic et al. 2017). Systematic conservation and evaluation of this variety could not only support local agricultural sustainability but also contribute to the preservation of valuable genetic diversity for future breeding programs.

Table 1. IPGRI description of studied Saransak garlic population

	7.1 Vegetative		
	The mark	Code	Description
	7.1.1 Foliage colour	4	Grey-Green
	7.1.5 Foliage attitude	5	Intermediate
	7.1.11 Shape of mature dry bulbs	5	Globe
	7.1.12 Shape of mature garlic bulb	1	Circular, basal plate prominent
	7.1.16 Bulb skin colour (garlic)	1	White
	7.1.16.2 Skin colour of the clove (garlic)	2	Yellow and light brown
	7.1.19 Number of cloves per compound bulb (garlic)	5	16–20
	7.1.20 Bulb structure type (garlic)	1	Regular multi-fan groups (or multi-shelled)
	7.1.21 Shape of the compound bulb in horizontal section (garlic)	2	Elliptic
	7.1.22 Weight of cloves (garlic)	2	2–4 g

Spring garlic, like Saransak, refers to garlic varieties planted in early spring and harvested in the same growing season, typically in late summer. Unlike hardneck garlic, which requires vernalization (a cold period) to form bulbs, spring garlic can develop under milder conditions, making it well suited for regions with shorter or less severe winters. It usually produces softer, more flexible necks and smaller cloves compared to fall-planted garlic (Montano et al., 2011).

The analysis of Saransak garlic bulb characteristics highlighted varying levels of uniformity across different traits, with some parameters demonstrating greater stability than others. Bulb weight (40.42 ± 6.82 g, CV = 16.88%) was a moderate indicator of consistency within the studied population (Tab. 2).

Table 2. Analysis of main bulb characteristic of Saransak garlic population

Characteristic	$\bar{X} \pm S\bar{x}$	CV
Bulb weight (g)	40.42 ± 6.82	16.88
No. of cloves	15.30 ± 2.83	18.50
No. of dry external scales of the bulb	6.63 ± 0.85	12.82
Bulb height (mm)	42.69 ± 3.89	9.11
Bulb diameter (mm)	43.93 ± 3.87	8.80
Clove weight (g)	3.28 ± 1.17	35.54
Clove height (mm)	36.14 ± 3.88	10.74
Clove diameter (mm)	13.71 ± 2.66	19.41
TSS (% Brix)	15.73 ± 3.56	22.65

This aligns with the findings of Santos et al. (2022) and Marodin et al. (2019), who reported that bulb weight is a key yield determinant with values significantly influenced by genetic and environmental factors. For instance, Dixit et al. (2023) reported a wide range of bulb weights (22.10 g to 70.60 g), depending on genotype and cultivation conditions. Clove weight of Saransak garlic (3.28 ± 1.17 g, CV = 35.54%), however, shows substantial variability, suggesting inconsistency in individual clove sizes, which can impact market acceptability and planting material selection. Literature indicates higher average clove weights (7.53 g) in other varieties, further emphasizing that Saransak garlic may have smaller cloves than some commercial varieties (Dixit et al., 2023). The number of cloves per bulb (15.30 ± 2.83, CV = 18.50%) was within the expected range, as Aswani (2024) noted a range of 5 to 15 cloves per bulb, with larger bulbs generally having more cloves. The morphological traits of Saransak garlic such as bulb height (42.69 ± 3.89 mm, CV = 9.11%) and bulb diameter (43.93 ± 3.87 mm, CV = 8.80%) exhibit low variability, suggesting a relatively stable bulb shape. These values are slightly lower than the ranges (bulb height: 45 – 70 mm; bulb diameter: 40 – 60 mm) reported by Lima et al. (2019).

The value of 6.63 ± 0.85 external dry scales per garlic bulb indicates a moderate level of morphological stability within the population, with some genetic and environmental variability influencing this trait. The standard deviation of 0.85 suggests that while the average number of scales is relatively consistent, individual bulbs can vary, which is supported by findings that show significant morphological variation among garlic accessions due to genetic diversity and environmental factors (Aswani, 2024; Sultan & Raina, 2020). A CV of 12.82% indicates that while variability exists, it is not extreme, suggesting that factors such as soil properties, plant nutrition, and growing conditions play a role in influence the number of dry scales (Oliveira et al., 2020). From an agronomic perspective, the presence of a moderate number of protective scales is advantageous for storage because it minimizes moisture loss and reduces the risk of pathogen entry (Barboza et al., 2022). This is particularly important for commercial garlic production, where uniformity in the bulb structure can enhance market value and processing efficiency. The relatively low variability in this trait is beneficial as it allows for more predictable storage outcomes. However, in open-pollinated or landrace populations, some degree of variation is expected, which can be harnessed through selective breeding to improve uniformity for commercial purposes (Jia et al., 2023).

In terms of clove characteristics, the clove height of 36.14 ± 3.88 mm, with a CV of 10.74%, suggests that this trait is largely stable and influenced more by genetic factors than environmental conditions. This consistency is beneficial for commercial production, as a uniform clove height contributes to a standardized appearance, which is crucial for processing and retail (Li et al., 2024). Conversely, the clove diameter of 13.71 ± 2.66 mm, with a higher CV of 19.41%, indicates that this trait is more variable and susceptible to environmental influences, genetic diversity and cultivation practices (Benke et al., 2020). The preference for larger clove diameters in culinary applications highlights the importance of this trait; however, excessive variability could complicate processing and packaging operations, necessitating further breeding efforts to enhance consistency (Benke et al., 2021). When considering these traits collectively, the stability of clove height juxtaposed with the variability in clove diameter suggests that, while certain aspects of garlic bulbs are consistent, others may benefit from targeted agronomic practices or selective breeding to improve uniformity. The observed variations in clove diameter and weight, along with the number of dry external scales, indicate potential areas for improvement in breeding programs aimed at enhancing garlic marketability and processing efficiency (Hirata et al., 2016; Thapa et al., 2021). The strong correlation between bulb size and weight is well-documented, as larger bulbs store more carbohydrates and nutrients, contributing to the overall yield potential (Li, 2024). A notable parameter in garlic quality assessment is total soluble solids – TSS (15.73 ± 3.56 % Brix, CV = 22.65%), which influences flavour intensity, processing quality and storage potential. The values observed in Saransak garlic were lower than those reported for some high-quality cultivars, where TSS levels above 44% have been associated with improved flavour and storage capacity (Dixit et al., 2023). Studies have indicated that higher dry matter content improves garlic quality (Atif et al. (2020), while Goyal et al. (2022) confirming that TSS variability is influenced by genotype, soil fertility and irrigation practices. The moderate variation in Saransak garlic TSS suggests that both genetic and environmental factors may play a role in the observed differences. Overall, the comparison with the literature suggests that Saransak garlic exhibits stable bulb morphology, with some variability in clove weight and TSS content, which are critical traits for market acceptance. Although bulb size traits align with reported values in other garlic cultivars, the variability in clove weight and TSS could be addressed through breeding and selection programs to improve consistency and enhance overall quality. Future studies should further investigate the environmental and genetic factors that influence these variations to optimize production and marketability.

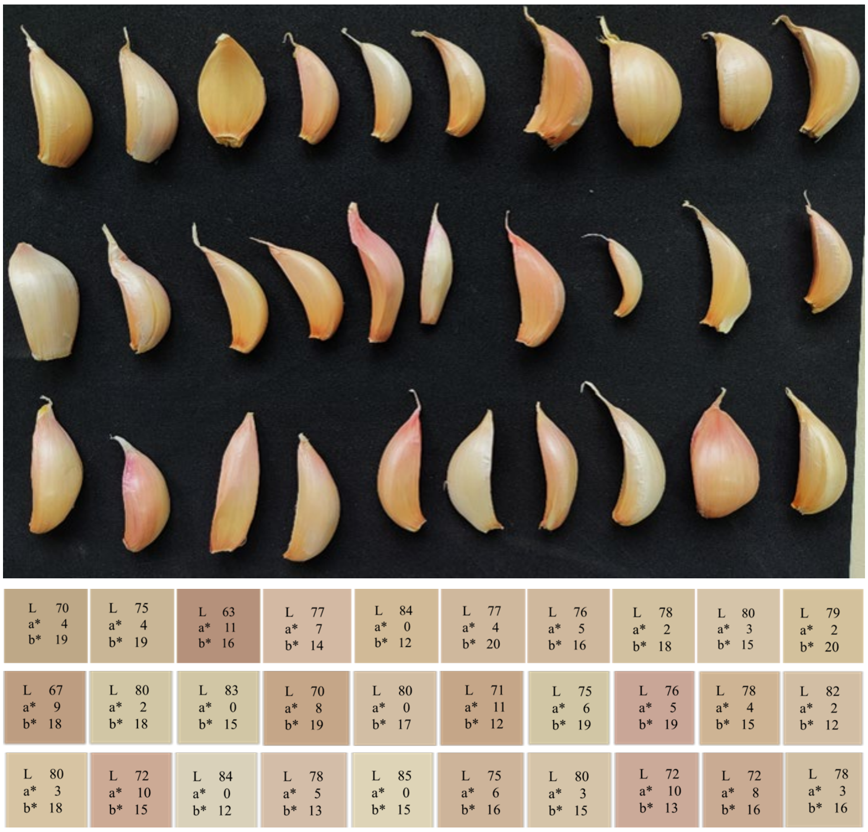

Figure 2. Colorimetric analysis of selected cloves of Saransak garlic

Cloves of the autochthonous garlic population from the Ljubinje region are shown in Fig. 2. exhibited distinct coloration patterns. The outer tunic of the cloves is predominantly light beige to pale brown, with subtle pinkish or purplish hues, indicative of specific phenolic compounds and flavonoids that may contribute to its adaptability and potential bioactive properties. The inner layers of the tunic transition to a creamy white colour, ensuring effective protection of the fleshy storage tissue. The vibrant yellowish spots in the central part of the cloves suggested the presence of sulphur-containing compounds, which are crucial for the characteristic pungency and potential health benefits of garlic. This coloration is important in commercial production because it can serve as a visual indicator of authenticity and quality. The presence of pinkish or purplish pigmentation in the tunic can be associated with resistance to environmental stress factors, including UV radiation and microbial infections, enhancing postharvest durability. Additionally, the rich sulphur content inferred from the yellowish areas is essential for both culinary value and medicinal properties, increasing consumer demand for nutritionally superior and locally adapted garlic varieties. Therefore, the distinct clove coloration of this autochthonous population supports its potential for niche market branding and commercial expansion beyond the local gardens (Liu et al., 2019). Colorimetric analysis using the *L**, *a**and *b** colour spaces is a valuable tool for assessing garlic quality, particularly during processing. This objective approach measures colour changes that can indicate alterations in chemical compounds and the overall product quality. The researchers measured the *L** (lightness), *a** (red-green axis) and *b** (blue-yellow axis) values of the garlic samples to assess the impact of various drying conditions on colour retention. Their findings highlight the effectiveness of colorimetric analysis in monitoring quality changes during garlic processing. Colorimetric analysis of garlic is useful for evaluating skin and clove colour which can be linked to variety, storage conditions or processing effects. For instance, a shift from negative *a** (greenish) to positive *a** (reddish) could indicate changes in the pigment composition (Elnemr et al., 2022).

CONCLUSION

The autochthonous garlic population Saransak from the Ljubinje region exhibits a well-adapted morphological structure and unique characteristics, making it a promising candidate for local variety and commercial cultivation. Its compact, globular bulb shape, along with a robust fibrous root system, ensure effective nutrient uptake and strong anchorage. The cloves are consistently elongated and slightly curved, protected by a light-coloured tunic that offers resistance to desiccation and mechanical damage, whereas the internal storage tissue rich in fructans, supports drought resistance and energy storage. The population's clove coloration, from light beige to pale brown with pinkish hues, signals the presence of bioactive compounds, such as flavonoids and sulphur, enhancing its adaptability, health benefits and culinary value. Although bulb characteristics such as weight, height and diameter exhibit low variability, clove weight and total soluble solids show higher variation, indicating the potential for improvement in clove uniformity and flavour. The genetic stability and adaptation of this garlic population to local agroecological conditions position it well for organic cultivation and sustainable agricultural practices, with significant potential for branding as a regional specialty product. These findings emphasize the importance of systematic conservation and evaluation of Saransak garlic to preserve its unique genetic traits, which could contribute to future breeding programs aimed at enhancing garlic quality and consistency, while promoting local agricultural sustainability.

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