Morphological variability and mineral composition of three garlic genotypes cultivated in Korça region, Albania

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Abstract

Garlic (Allium sativum L.) is a popular vegetable of the Allium genus cultivated in Albania. The Korça region is mainly known for its high-quality garlic bulbs. In this study, we examined two local garlic landraces, 'Korça' and 'Puka,' and an introduced cultivar referred to by farmers as 'Dutch garlic' or simply 'Dutch.' These genotypes' morphological and chemical compositions were analyzed, revealing a wide range of diversity in their bulb features. Notably, the introduced cultivar, 'Dutch, ' demonstrated numerous unique characteristics compared to the local landraces, highlighting the impact of genotype on the observed diversity in morpho-biometrical features and mineral composition. The mineral composition of all garlic genotypes cultivated in the Korça region was found to be rich, with calcium (Ca) being the predominant mineral, followed by potassium (K), magnesium (Mg), iron (Fe), zinc (Zn), and sodium (Na). The significant mineral content found in these genotypes underscores their potential as a valuable source of nutrients for human nutrition. The landrace 'Korça' and the introduced cultivar 'Dutch' demonstrated high morphological characteristics and mineral composition, meeting the expected quality standards for garlic. This study underscores the importance of genetic diversity in enhancing cultivated garlic's agronomic potential and nutritional value.

Keywords: Garlic morphological features, mineral absorption, functional food.

Introduction

Garlic (*Allium sativum* L.) is believed to be originated in central Asia, in Kazakhstan (Galgaye & Deresa 2023), and is one of the most economically important species belonging to the *Allium* genus of the Alliaceae family (Petropoulos et al., 2018; Beşirli et al., 2022), widely cultivated worldwide as a vegetable, spice and medicinal plant since ancient (Al-Safadi et al., 2003; Ijaz et al., 2015; Hahn et al., 2022; Beşirli et al., 2022; Kıraç et al., 2022). According to FAO Stat with data for 2022, garlic in the world is cultivated in around 1,662,346 ha with a production of 29,149,437 tons, while in Albania, it is grown around 1,174 ha with garlic and with a productivity of 19,038 tons

Fresh leaves and garlic cloves are used raw and cooked in cooking worldwide (Kıraç et al., 2022). Garlic is an appreciated human food presenting high carbohydrate, phosphoric, and sulphuric acids, proteins, and mineral salts contents, as well as antioxidant, antimicrobial, anti-inflammatory, anti-thrombosis, anti-cancer, and anti-atherosclerosis properties (Hahn et al., 2022).

Garlic is considered a rich source of volatile compounds (Kimbaris et al., 2006); it comprises at least 33 sulfur compounds, several enzymes, and minerals (Ishtiaq et al., 2017), which are responsible for the distinct flavor and the bioactive properties of dry bulbs (Kimbaris et al., 2006). There is also a high content of non-volatile compounds with well-known medicinal and therapeutic properties, such as amides, nitrogen oxides, phenolic compounds, especially flavonoids, proteins, saponins and sapogenins, as well as antioxidants, minerals (especially P, K and Se) and vitamins (especially vitamin C and vitamins of B complex) (Rekowska & Skupie, 2009**;** Petropoulos et al., 2018).

According to Kıraç et al. (2022), the volatile organosulfur compounds contained in garlic provide the typical intense aroma and are responsible for many medicinal properties that improve the immune system and may contribute to the prevention and treatment of diseases such as obesity, cardiovascular disorders, gastric ulcer, and cancer.

Genotype has a significant effect on the chemical composition of garlic bulbs. Therefore, following the climate requirements and market quality standards, cultivar choice is essential to the quality improvement of the final products (Petropoulos et al., 2018). Although garlic is propagated asexually with cloves in many areas of the world by farmers, have a great diversity in morphological and agronomic characteristics, primarily due to the existence of various ecotypes that are cultivated in the same areas for a long time and the consequent accumulation of natural mutations (Avato et al., 1998; Mohammadi et al., 2014; Petropoulos et al., 2018; Galgaye & Deresa, 2023). Growing conditions and cultivation practices also have an essential effect on the chemical composition of garlic bulbs. In particular, fertilization regimes and soil properties (physical, chemical and biological (Turan et al., 2017)) may have a significant effect on bulb quality features, such as dry matter, protein and total soluble solids content, pungency and mineral composition of dry garlic bulbs (Diriba-Shiferaw et al., 2014; Turan et al., 2017; Petropoulos et al., 2018), and the state of the plant's maturity at harvest (Turan et al., 2017).

Macro- and micro-elements in food are necessary because of their nutritional value and beneficial effects on human health (Beşirli et al., 2022). Crops are the primary source of minerals and vitamins, so micronutrient-related malnutrition can be solved by increasing the consumption of vegetable products (Gambelli et al., 2021). In addition, it is known that garlic belongs to the "functional foods" (Turan et al., 2017). Functional foods are products that contain various biologically active compounds and which, consumed in a current diet, contribute to maintaining the optimal state of physical and mental health of the population, and contain biologically active compounds with the potential to improve health or to reduce risk of disease (Butnariu & Sarac, 2019). The active compounds are phytochemicals, such as allicin in garlic (Bruulsema, 2000). Improving human nutrition by increasing the availability of trace minerals in crops is potentially highly efficient and effective (ABFF, 2007).

The chemical composition and content of bioactive compounds in garlic, which determines its quality, strongly depend on a genotype and growing conditions (Martins et al., 2016). Genetic diversity among different garlic populations and ecotypes is exploited to select germplasms with a higher content of bioactive compounds (Martins et al., 2016).

This study evaluated the diversity of morphological features and mineral composition of three garlic genotypes, including two local landraces and one imported commercial cultivar cultivated in the Korça region.

MATERIALS AND METHODS

Field observation and samples of garlic bulbs were collected during the growing season of 2015-2016 (autumn to summer) at full maturity and after curing at Bulgarec village in Korça field, which is located in South East of Albania with an altitude of 820 – 950 m above the sea level. Korça field has a Mediterranean continental climate, with a dry and hot summer and a cold and wet winter. It is the driest (760 mm rainfall on average per year) and coldest (up to –27ºC) region of Albania. Two Albanian landraces of garlic, namely 'Korça' and 'Puka,' and an introduced cultivar of Dutch origin, called by the farmer 'Dutch garlic,' or simple 'Dutch,' were analyzed for morphological and chemical composition. All three cultivars were cultivated on the same field and under the same agronomic and climatic conditions.

According to the Guidelines for the Conduct of Tests for Distinctness (GCTD), Uniformity and Stability Garlic *(Allium sativum* L.) (2001) of the International Union for the Protection of New Varieties of Plants, was compile the table of characteristics for each garlic genotype. In this study, only the bulb and clove characteristics were evaluated, and macronutrient analysis was determined using standard analytical methods described by the American Organization of Analytical Chemists International (AOAC International) procedure. The chemical composition was analyzed in the University of Thessaly lab. The chemical composition and phenotype features were analyzed using a one-way analysis of variance followed by Tukey's Honest Significant Difference (HSD) and Fisher's least significant difference (LSD) test, which was made for $\alpha = 0{,}05$.

RESULTS AND DISCUSSION

The bulb morphological features, according to GCTD, exhibited a high diversity between the studied garlic genotypes (Table 1). Differences were observed in all the morphological features between landraces and the 'Dutch' cultivar. The two landraces of garlic cultivated in the Korça region have shown similarities in most of the studied morphological features; this is probably due to the adaptation to specific growing conditions and clonal selection from farmers throughout the long period of cultivation. The difference between the two landraces was only in the number of cloves. 'Korça' cultivar had 11 – 15 cloves, and the 'Puka' cultivar had 16 – 20 cloves per bulb, whereas the 'Dutch' cultivar had 5 – 10 cloves per compound bulb. The presence of external cloves on both landraces is undesirable because it causes a distorted structure and reduces the market value of the products. According to Kıraç et al. (2022), such a phenomenon may occur due to environmental conditions and genetic-based changes. The tendency to form external cloves causes a distorted shape structure and reduces the market value of the products (Kıraç et al., 2022), shifting the quality requirements from extra class to first or second class, depending on the percentage of bulbs with external cloves (UNECE Standard FFV-18 Garlic, 2017).

The statistical analyses show significant variations in the quantitative traits of bulb and clove. According to Table 2, the bulb weight of the 'Dutch' (42,789±4,117 g) and 'Korça' (43,623±8,046 g) genotypes has no significant difference. Still, these two genotypes statistically differ in bulb weight among the 'Puka' genotype (31,064±7,308 g) for the HSD_{005}=7,440. The same differences were shown for the length and diameter of the garlic bulb, where the 'Dutch' and 'Korça' genotypes do not have significant differences. Still, both have differences with the 'Puka' genotype, which has the bulb's most petite length and diameter.

According to the United Nations Economic Commission for Europe Standard for Garlic (2017), the minimum diameter requirement for the extra class is 45 mm. This requirement is met only by the 'Korça' (46,400±3,026 mm) and 'Dutch' (48,650±2,237 mm) genotypes, while the 'Puka' genotype meets the requirement for the first and second classes.

The ratio length/diameter (L/D) has a higher value on two landraces, 'Korça' (0,837±0,063) and 'Puka' (0,820±0,073). There is no significant difference between them, but both significantly differ with the L/D ratio of the 'Dutch' genotype (0,745±0,033) for HSD_{005}=0,0655.

The current study indicated that the 'Dutch' genotype has a higher weight of cloves (4,815±1,407 g) and observed a significant difference with two landraces 'Korça' (2,326±0,895 g) and 'Puka' (2,058±0,790 g) for HSD005=1,159. Still, there was no significant difference between the clove weight of the two landraces. The same difference was shown in the length of the clove when the Dutch genotype had a higher length of clove (30,600±2,119 mm) with a significant difference with 'Korça' (25,400±3,864 mm) and 'Puka' genotypes (26,400±2,951 mm) for HSD005=3,395 mm. In contrast, there was no significant difference between the two landraces. Differences in the length of cloves were not demonstrated in diameter and L/D ratio (Table 2).

According to the literature (Martins et al., 2016; Petropoulos et al., 2018), genotype significantly affects garlic bulbs' chemical composition. To determine this effect of genotype, seven mineral compositions on garlic bulbs (K, Na, Ca, Mg, Mn, Fe, and Zn) were analyzed, expressed as mg/100 g fresh weight (Table 3) and in mg/100 g of dry weight (Table 4). The tables show that all three genotypes absorb K and Ca in high quantities.

Data illustrated in Table 3 shows that Ca is the main mineral in garlic bulbs, from 639±227 mg/100 g fresh weight in the Dutch genotype to 709±163 mg/100 g fresh weight in the Korça genotype. Still, statistically, this is not a significant difference for LSD_{005}=231 mg/100 g. In addition, there was no significant difference in the accumulation of Mg and Mn in the fresh garlic bulb. Genotype ‘Korça’ accumulates more K (365±20 mg/100g fresh weight) and significantly differs only from genotype ‘Dutch’ (334±15 mg/100g fresh weight). Also, there was no significant difference between genotypes ‘Dutch’ and ‘Puka’ (349±25 mg/100g fresh weight) for LSD_{005}=20 mg/100 g fresh weight. Genotype ‘Puka’ has a high concentration of Na in its bulb (25,9±2,4 mg/100g fresh weight) and has significance difference between genotypes ‘Dutch’ (18,3±3.2 mg/100g fresh weight) and ‘Korça’ (12,3±4.4 mg/100g fresh weight), also genotypes ‘Dutch’ and ‘Korça’ has significance difference for LSD_{005}= 3,3 mg/100g fresh weight. Accumulation of Fe was higher in ‘Dutch’ genotype (4,91±0,90 mg/100g fresh weight) and with significant difference compared with landraces ‘Korça’ (3,82±0,57 mg/100g fresh weight) and ‘Puka’ (3,32±0,54 mg/100g fresh weight). Still, there was no significant difference between the two landraces (LSD_{005}= 0,67 mg/100g fresh weight). Zn accumulation shows a significant difference between the three genotypes. Dutch has the highest accumulation with 0,67±0,09 mg/100g fresh weight, followed by ‘Korça’ 0,48±0,10 mg/100g fresh weight and ‘Puka’ 0,34±0,11 mg/100g fresh weight, for LSD_{005}= 0,10 mg/100g fresh weight.

The main mineral in all garlic genotypes is Ca, followed by K and Mg, Fe, Zn, and Na in considerable amounts. Although the value of mineral composition on garlic bulb on studied genotypes was higher than in the literature, the same ratio of mineral composition was also reported by Hacıseferoğulları et al. (2005), Akinwande and Olatunde (2015), Vadalà et al. (2016), and Petropoulos et al. (2018).

The high diversity of mineral accumulation was shown in garlic bulbs between genotypes expressed as mg per 100 g of dry weight (Table 4). Ca was the mineral with the highest concentration in all three genotypes, with 1885±434 mg/100 g of dry weight in the ‘Korça’ genotype, followed by ‘Puka’ 1673±747 mg/100 g of dry weight and ‘Dutch’ 1486±528 mg/100 g of dry weight. However, there is no significant difference between them for LSD_{005}= 569 mg/100 g of dry weight. Although Mg has a high concentration on the dry mass of the bulbs, there was no significant difference between genotypes. Accumulation of K is higher in ‘Korça’ genotype 971±53 mg/100 g of dry weight, followed by ‘Puka’ 862±62 mg/100 g of dry weight and ‘Dutch’ 776±34 mg/100 g of dry weight. All data shows a significant difference for LSD_{005}= 50 mg/100 g of dry weight. Na concentration shows a significant difference between genotypes. Genotype ‘Puka’ has a high value of 64±5,8 mg/100 g of dry weight, followed by ‘Dutch’ 42,7±7,4 mg/100 g of dry weight and ‘Korça’ 32,7±11,7 mg/100 g of dry weight. The concentration of Mn in the ‘Korça’ genotype (4,23±0,24 mg/100 g of dry weight) has a significant difference with ‘Puka’ 3,80±0,10 mg/100 g of dry weight and ‘Dutch’ 3,66±0,09 mg/100 g of dry weight, but the last two genotypes do not show significance difference for LSD_{005}= 0,15 mg/100 g of dry weight. Fe accumulation is higher in genotypes

‘Dutch’ 11,41±2,10 mg/100 g of dry weight, and ‘Korça’ 10,15±1,52 mg/100 g of dry weight, and those values have significant differences with the value of ‘Puka’ genotype 8,20±1,34 mg/100 g of dry weight, but not between them (LSD_{005}= 1,64 mg/100 g of dry weight). The highest concentration of Zn was in genotype Nederland 1,56±0,20 mg/100 g of dry weight, followed by Korça genotype 1,27±0,26 mg/100 g of dry weight, and then Puka genotype 0,85±0,26 mg/100 g of dry weight (LSD_{005}= 0,24 mg/100 g of dry weight).

Garlic belongs to the functional foods group with bioactive ingredients (minerals, vitamins, probiotics, and fibers) thought to enhance health and fitness. Table 5 shows that three genotypes cultivated in the Korça region are a good source of minerals for adult men and women, compared with the recommended daily value. If we consider consuming 10 g garlic (cultivated in Korça field) per day (3 – 4 cloves per day), an adult can take around 8% of the daily value of Mn, 7% of Ca, 3,3 % Fe, 1,8% Mg, 0,7 % K and Zn, and 0,17% Na.

CONCLUSIONS

The garlic genotypes cultivated in the Korça region revealed a significant ($p > 0.05$) variation in their morphological features and mineral composition. Variability in morphological traits and mineral composition was observed between the examined landraces and the introduced genotype and between landraces. However, not all trait changes of landraces were statistically proven. The observed similarity in the traits among the examined landraces can be explained by adapting to the specific growing condition. Findings highlighted that genotype may significantly affect chemical composition and nutritional value and, consequently, the quality of the garlic bulb. Garlic belongs to the group “functional foods,” and genotypes cultivated in the Korça region are a good source of minerals. Despite the diversity in the mineral composition, the garlic grown in the Korça region is a good source of minerals and other bioactive elements related to mineral composition, and this makes the garlic a functional food that is not to be missed on our tables. The study has shown that ‘Korça’ and ‘Dutch’ garlic genotypes had high indicators of morphological features and mineral composition, meeting the expected quality standards for the market. The properties of the local landraces evidenced in this work may be attractive for promoting their consumption. They can be used in future garlic selection studies to improve local landraces or to develop new high-yield and high-quality garlic cultivars.

Table 1. Plant and bulb morphological features, according to the Guidelines for the Conduct of Tests for Distinctness

Genotypes	Shape of mature, dry bulbs	Shape of mature garlic bulb	The outer skin color of the bulb	The skin color of the clove	Number of cloves per compound bulb	Bulb structure type	The shape of the bulb in the horizontal section	Weight of cloves	Position of cloves at the tip of the bulb	Bulb shape of the base	Bulb distribution of cloves	Bulb external cloves
'Dutch'	Flat globe	Broadly ovate, basal plate even	White with Violet stripes	Mixed	5 – 10	Regular two-fan groups	Circular	>4 – 6 g	Inserted	Rounded	Radial	Absent
'Puka'	Broad oval	Broadly ovate, basal plate even	White	Yellow and light brown	16 – 20	Regular multi-fan groups	Mixture	2 – 4 g	Exerted	Recessed/ (Rounded	Non-radial	Present
'Korça'	Broad oval	Broadly ovate, basal plate even	White	Yellow and light brown	11 – 15	Regular multi-fan groups	Mixture	2 – 4 g	Exerted	Recessed/ (Rounded	Non-radial	Present

Table 2. Statistical analyses of bulb and clove features

	Bulb				Clove			
	Mass [g]	Length [mm]	Diameter [mm]	Ratio L/D	Mass [g]	Length [mm]	Diameter [mm]	Ratio L/D
'Dutch'	42,789±4,117a	36,200±1,874a	48,650±2,237a	0,745±0,033b	4,815±1,407a	30,600±2,119a	16,700±2,983a	1,905±0,482a
'Puka'	31,064±7,308b	34,400±3,596b	42,040±3,678b	0,820±0,073a	2,058±0,790b	26,400±2,951b	14,700±3,401a	1,865±0,407a
'Korça'	43,623±8,046a	38,900±4,383a	46,400±3,026a	0,837±0,063a	2,326±0,895b	25,400±3,864b	13,900±3,900a	1,917±0,467a
HSD_{005}	7,440	3,822	3,368	0,0655	1,159	3,395	3,823	0,502

Table 3. Mineral composition of the studied garlic genotypes expressed in mg per 100 g of fresh weight (mean values±SD).

Genotypes	K	Na	Ca	Mg	Mn	Fe	Zn
'Dutch'	334±15b	18,3±3,2b	639±227a	69,3±24,8a	1,58±0,04a	4,91±0,90a	0,67±0,09a
'Puka'	349±25ab	25,9±2,4a	677±302a	72,9±23,9a	1,54±0,04a	3,32±0,54b	0,34±0,11c
'Korça'	365±20a	12,3±4,4c	709±163a	69,0±21,6a	1,59±0,09a	3,82±0,57b	0,48±0,10b
LSD	20	3,3	231	22,8	0,06	0,67	0,10

Table 4. Mineral composition of the studied garlic genotypes expressed in mg per 100 g of dry weight (mean values±SD).

Genotypes	K	Na	Ca	Mg	Mn	Fe	Zn
'Dutch'	776±34c	42,7±7,4b	1486±528a	161±58a	3,66±0,09b	11,41±2,10a	1,56±0,20a
'Puka'	862±62b	64±5,8a	1673±747a	180±59a	3,80±0,10b	8,20±1,34b	0,85±0,26c
'Korça'	971±53a	32,7±11,7c	1885±434a	183±57a	4,23±0,24a	10,15±1,52a	1,27±0,26b
LSD	50	8,4	569	56	0,15	1,64	0,24

Table 5. Mineral composition of studied garlic genotypes and recommended daily value intake in mg per 100 g

Genotypes		K	Na	Ca	Mg	Mn	Fe	Zn
'Dutch'		334	18,3	639	69,3	1,58	4,91	0,67
'Puka'		349	25,9	677	72,9	1,54	3,32	0,34
'Korça'		365	12,3	709	69,0	1,59	3,82	0,48
Daily requirements*	For men	4700	1500	1000	420	2,3	8	11
	For women	4700	1500	1000	320	1,8	18	8
	10g	0,7%	0,17%	7%	1,8	8%	3,3%	0,7%

*https://www.hsph.harvard.edu/nutritionsource/vitamins/; Driskell, 2009; Interactive Nutrition Facts Label 2021

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