Original scientific paper
DOI: /10.5513/JCEA01/25.4.4321
Journal of Central European Agriculture, 2024, 25(4), p.978-987

Evaluation and comparison of morphological traits in garlic as influenced by year and genotypic diversity

Evaluarea și compararea trăsăturilor morfologice la usturoi influențate de ani și de diversitatea genotipică

Patricia Maria POPA[1], Sina COSMULESCU[2] (✉)

[1] Doctoral School of Plant and Animal Resources Engineering, Faculty of Horticulture, University of Craiova, 13 A.I. Cuza Street, 200585, Craiova, Romania

[2] Department of Horticulture and Food Science, Faculty of Horticulture, University of Craiova, 13 A.I. Cuza Street, 200585 Craiova, Romania

✉ Corresponding author: sinacosmulescu@hotmail.com

Received: March 15, 2024; Accepted: May 31, 2024

ABSTRACT

The present study aimed to evaluate and analyse the variation of morphological parameters in garlic according to genotype and crop year, to obtain valuable insights for identifying genotypes with superior performance under specific environmental or cultivation conditions. Fifteen autumn garlic genotypes selected from the Oltenia region, Romania, and the registered 'Benone' variety, cultivated in the Craiova area, were evaluated over two consecutive years (2022 and 2023). The study's results revealed significant differences among genotypes for all analysed traits (bulb weight, bulb size, number of cloves), highlighting the influence of both genotype and year on these characteristics. Notably, genotype M15 exhibited the highest bulb weight (49 g). Local genotypes outperformed the registered variety, underscoring the superiority of the selected genotypes and their value for breeding or cultivation purposes. These findings provide important insights for selecting garlic genotypes based on specific environmental conditions and cultivation requirements. The information obtained may contribute to improving garlic production and quality in the Oltenia region, as well as promoting genetic diversity and crop sustainability.

Keywords: *Allium sativum*, variability, bulb, morphological characteristics, Romania

REZUMAT

Prezenta lucrare a avut ca scop să evalueze și analizeze variația unor parametri morfologici la usturoi în funcție de genotip și anul de cultură, pentru a obține informații valoroase în vederea identificării genotipurilor cu performanțe superioare în anumite condiții de mediu sau de cultură. Au fost evaluate și analizate 15 genotipuri de usturoi de toamnă, selectate din zona Oltenia, Romania și soiul omologat 'Benone', cultivate în zona Craiova, timp de doi ani consecutivi (2022 și 2023). Rezultatul studiului a arătat diferențe semnificative între genotipuri pentru toate trăsăturile analizate (greutate bulb, dimensiunea bulbului, numărul de bulbili) și a pus în evidență influența soiului și anului asupra caracteristicilor. Se remarcă genotipul M15 pentru greutatea bulbului (49 g). Genotipurile locale au depășit soiul omologat, ceea ce pune în evidență superioritatea genotipurilor selecționate și valoarea lor pentru ameliorare sau cultură. Aceste constatări oferă informații importante pentru selecția genotipurilor de usturoi în funcție de condițiile de mediu și de cerințele de cultură specifice. Informațiile obținute pot fi utile pentru îmbunătățirea producției și calității usturoiului în zona Oltenia, precum și pentru promovarea diversității genetice și a durabilității culturilor.

Cuvinte-cheie: *Allium sativum*, variabilitate, bulb, caractere morfologice, România

INTRODUCTION

Garlic (*Allium sativum* L.) is among the oldest cultivated plants and one of the most important bulb vegetables (Alam et al., 2016), whose morphological development can be influenced by both environmental factors and its genotype. The quality and yield of garlic production can be affected by several factors, including growing conditions, crop management, and the cultivated variety. Various factors such as biotic and abiotic stress, mineral nutrition, and precipitation levels, can influence production yield (Cortés et al., 2003; Rekowska and Skupień, 2007; Mirzaei et al., 2007). Garlic exhibits distinct growth characteristics, undergoing a period of low temperatures in the initial phase, followed by a period of high temperatures and long days to induce bulb formation (Bandara et al., 2000; Rahim and Fordham, 2001). There is considerable fluctuation in garlic production and prices because it is primarily grown outdoors and is vulnerable to weather conditions (Badran, 2015). Stress caused by climate change can lead to significant changes in morpho-anatomical, physiological, and biological traits in crops. Air temperature and atmospheric precipitation are major abiotic factors that affect plant growth and development (Tchorzewska et al., 2017). Precipitation before garlic harvesting, accumulated sunlight hours, evapotranspiration, and days with optimal temperature have positive effects on garlic bulb weight.

In addition to environmental factors, garlic genotype or variety also plays a crucial role in determining the morphological characteristics of the plant. Genotype, temperature, photoperiod, and planting time have significant effects on the growth period, plant height, bulb weight, and flowering rate (Wu et al., 2016). Due to the significant genotype-environment interaction, bulb growth time and production vary significantly from year to year, from planting date to location. Global garlic progress indicates that the genetic plasticity of garlic is attributed to unstable environmental conditions worldwide (Ahmad et al., 2023). Genotype determines aspects such as bulb size, nutrient content, disease and pest resistance, and maturation time. A particular genotype may be adapted to certain environmental conditions but may be less suitable for others (Petropoulos et al., 2018; Akan, 2019). In Romania, garlic has diverse varieties, each with its genetic characteristics (Popa et al., 2023; Popa and Cosmulescu, 2023). It is important for farmers to select the appropriate garlic varieties for their specific environmental conditions and to use management practices that maximise the genetic potential of plants within these conditions. Therefore, achieving optimal yield and quality depends on a balanced combination of plant genotype and the environment in which they are cultivated. In this regard, the study aims to evaluate and analyse the variation of morphological parameters in garlic according to genotype and year of cultivation to obtain valuable information for identifying genotypes with superior performance under specific environmental or cultural conditions.

MATERIALS AND METHODS

Biological material

Fifteen autumn garlic genotypes (CR14, IZ6, RC12, PV8, SS4, GH2, DB11, CN7, PL1, DG3, GR5, OR10, BR9, M15, DB13) and the certified 'Benone' variety were studied. One genotype (M15) belongs to the hard-neck garlic group (*A. sativum* sub var. *ophioscorodon*), while all other genotypes are soft-neck type (*A. sativum* sub var. *sativum*). The crop layout was established with the following distances: 25 cm between rows, 6-8 cm between plants/row, and planting depth of 5 cm.

Research location

Observations were conducted in an experimental plot in the northern part of Craiova city (44°21'55" N / 23°48'18" E). Meteorological characteristics including temperature, precipitation, humidity, and solar radiation during the research period are presented in Table 1.

The total precipitation for the 2021/2022 season was 517.6 mm, 199.9 mm less than the total precipitation for the 2022/2023 season (717.5 mm). The temperature difference between the two seasons is relatively small, at +0.6 °C in the 2022/2023 season, where the monthly temperature average reached 13.30 °C.

Table 1. Monthly average temperatures (°C), monthly precipitation (mm), and average solar radiation (W/m²) for the 2021-2022 and 2022-2023 growing seasons

Month/Year	Temp. (°C)	Precip. (mm)	Solar R. (W/m²)	Month/Year	Temp. (°C)	Precip. (mm)	Solar R. (W/m²)
October 2021	11.91	44.6	108.7	October 2022	15.58	27	172.95
November 2021	9.26	56.4	60.68	November 2022	11.21	93.2	78.64
December 2021	4.31	35	51.57	December 2022	4.6	110	48.99
January 2022	3.66	76.2	93.12	January 2023	6.03	76.2	52.62
February 2022	6.89	77.8	121.45	February 2023	5.35	100.6	132.31
March 2022	6.85	5.8	154.76	March 2023	10.7	95.2	183.23
April 2022	13.3	117.8	176.21	April 2023	12.44	0.2	51.24
May 2022	19.75	117.4	243.56	May 2023	17.6C	36.3	177.84
June 2022	24.46	63	182.27	June 2023	22.2	111.2	166.52
July 2022	26.68	41	217.2	July 2023	27.25	67.6	228.59
	X = 12.70	∑ = 517.6	X=140.95		X = 13.30	∑ = 717.5	X=129.29

Temp. = temperatures, Precip. = monthly precipitation, Solar R. = average solar radiation, X = mean, ∑ = Total

The soil is characterized by pH – 6.31, humus content 1.8%, nitrogen content: nitrites - <0.25 mg/kg, nitrates – 96.6 mg/kg; chemical element content: phosphorus – 496 mg/kg, potassium – 5410 mg/kg, magnesium – 4310 mg/kg, sodium – 260 mg/kg, iron – 23700 mg/kg, zinc - <50 mg/kg.

Method

The experiment was conducted on a farm field near Craiova, Romania (44°21'55" N, 23°48'18" E) during the growth seasons of the years 2021/2022 and 2022/2023. The bulbs were planted in the last decade of October, for both seasons. The experiment was laid out in a Randomized Complete Block Design with three replications and each replication consisted of forty plants. All the genotypes were randomized separately in each replication. The crop layout was established with the following distances: 25 cm between rows, 6-8 cm between plants/row, and planting depth of 5 cm. Various aspects such as bulb weight, bulb height, bulb diameter, and the number of cloves per bulb were analysed at 40 days post-harvest. Observations were conducted during the growth seasons of the years 2021/2022 and 2022/2023, following the standard descriptors for garlic developed by the International Plant Genetic Resources Institute (IPGRI, ECP/GR, AVRDC, 2001).

Statistical analysis

All morphological data collected over the two years were compiled into an Excel database and subsequently subjected to statistical processing. Mean, standard deviation and coefficient of variation were calculated for each genotype. The results were processed in Microsoft Excel 2010 and IBM SPSS Statistics 26.0 software. Bifactorial ANOVA analysis and Duncan multiple range tests at $P < 0.05$ were used.

RESULTS AND DISCUSSION

Phenotypic variation

The mean, minimum, maximum, and coefficient of variation for garlic genotype characteristics over two calendar years are presented in Table 3. Morphological traits (bulb weight, bulb height, bulb diameter, number of cloves per bulb) were utilized to investigate and define morphological differences among genotypes. Mean values and coefficients of variation serve as indicators for selecting phenotypic characteristics of interest for breeding purposes. Post-harvest evaluations revealed that bulb weight was the character with the highest coefficient of variation (CV = 22.73-51.32%), followed by the number of cloves (CV = 31.84-54.89%). Mean bulb weight values exceeded those of the control in both years of study, highlighting the superiority of selected genotypes and their value for breeding or cultivation. The considerable variability regarding bulb weight may also be attributed to variations in bulb size at planting. It is considered that the size of cloves used for planting affects the size of the harvested bulb, and there exists a linear relationship where bulb size significantly increases as planted bulb size increases (Drăghici and Lagunovschi-Luchian, 2015). Similarly, Castellanos et al. (2004) described that garlic productivity and profitability are affected by bulb size used for planting, planting density, and planting method. According to Desta et al. (2021), bulb size is an important characteristic significantly influencing all growth parameters and yield of garlic. In the present study, considering bulb weight, the estimated garlic yield per hectare, depending on genotype, under the same climatic conditions and cultivation technology, is presented in Table 2.

It is observed that the selected genotypes are much more productive (15.71-15.82 t/ha) compared to the control, the 'Benone' cultivar (8.34-10.51 t/ha), highlighting the superiority of the genotypes for this characteristic. Starting from bulb weight and calculating productivity, the average yield of garlic genotypes, averaging around 15 t/ha, is higher than the global average garlic yield (6 t/ha). This implies that selection among the analysed genotypes will allow the introduction of new individuals with high yields into cultivation. The genotypes are selected from Oltenia, a region where they have been cultivated for several years, and therefore, it is likely that long-term clonal selection has been carried out by local farmers in this area. The height and diameter of the bulb were the characteristics with the lowest coefficient of variability, suggesting that these are cultivar traits, less influenced by cultivation and environmental factors. The ratio between bulb length and diameter was used to assess their shape. Variation limits for bulb height ranged between 2.03 and 6.20 cm in 2022 and between 2.76 and 6.20 cm in 2023. Regarding the number of cloves per bulb, the mean ranged between 9.42 and 9.60. For the control variety 'Benone', the average value was 13.9 cloves per bulb in 2022 and 9.60 cloves per bulb in 2023. Weight and number of cloves are decisive quantitative characteristics that determine the utilization direction of garlic. Genotypes with fewer but larger cloves are suitable for industrial processing (Gvozdanovic-Varga et al., 2002).

Evaluation of garlic morphological traits determined by genotype

Table 4 presents the results obtained regarding the morphological variations of garlic bulbs for autumn varieties over two calendar years (2022 and 2023).

Table 2. Estimated garlic production per hectare depending on bulb size for the studied genotypes

Genotype	Yield (bulbs/ha)	Bulb weight (g)		Estimated production (t/ha)	
		2022	2023	2022	2023
'Benone' (Cv)	571428	18,41	14,60	10,51	8,34
Genotype 1...15	571428	27,70	27,51	15,82	15,71

Cv – certified variety

Table 3. Mean, minimum, maximum, and coefficient of variation (CV) of post-harvest traits evaluated in garlic genotypes

	Year	Genotype	Mean	SD	min	max	CV%
Bulb weight (g)	2022	G1-G15	27.70	13.01	6.8	82.83	46.96
		'Benone'	18.41	8.28	8.36	35.44	44.97
	2023	G1-G15	27.51	14.12	5.33	82.83	51.32
		'Benone'	14.60	3.32	9.3	18.97	22.73
Bulb height (cm)	2022	G1-G15	3.73	0.60	2.03	6.20	16.08
		'Benone'	3.53	0.48	2.95	4.51	13.59
	2023	G1-G15	4.38	0.68	2.76	6.20	15.52
		'Benone'	3.88	0.33	3.49	4.4	8.50
Bulb diameter (cm)	2022	G1-G15	4.29	0.73	2.51	6.84	17.01
		'Benone'	3.68	0.61	2.86	4.85	16.57
	2023	G1-G15	4.20	0.84	2.33	6.51	20
		'Benone'	3.39	0.29	2.91	3.74	8.55
Number of cloves/bulb	2022	G1-G15	9.42	3.00	1	17	31.84
		'Benone'	13.9	7.63	7	33	54.89
	2023	G1-G15	8.14	2.86	1	15	35.13
		'Benone'	9.60	4.57	4	20	47.60

X = mean, SD = Standard deviation; min=minimum; max = maximum; CV% = coefficient of variation

Duncan's test showed that garlic genotypes were significantly different in all evaluated parameters. As regards bulb weight, analysis of the data reveals considerable variability between genotypes. 'Benone' variety recorded an average value of 18.41 g in the first year and 14.60 g in the second year. Of the genotypes analyzed, 14 genotypes exceeded the average value recorded for the 'Benone' variety, the highest value recorded being for the M15 genotype (49.35-49.16 g), which indicates a potential superiority in garlic production of local genotypes, under the same specific growing conditions (environment and soil). A lower value than that recorded by the control variety was obtained in the GR5 genotype (16.23 g) in 2022. Regarding bulb weight, results obtained by Baghalian et al. (2006) showed variations between 18.66 and 47 g, analysed across 26 genotypes. In a study conducted by Kıraç et al. (2022), for 39 genotypes, the variation limits for bulb weight ranged from 30.449 g to 98.25 g. The diameter and height of the bulb were significantly different from one genotype to another for both years of research (Table 4). Regarding the height of the bulb, the 'Benone' variety recorded an average value of 3.55 and 3.88 cm, respectively, the rest of the genotypes recorded values in the range of 3.04 (GR5) - 4.65 cm (M15), respectively 3.70 (GR5) - 4.99 cm (PL1). Comparing with the literature, Singh et al. (2018), analysing 59 garlic genotypes, have recorded limit values between 3.41 cm and 6.06 cm. For bulb diameter, the values recorded by the control variety ('Benone') were 3.68 and 3.39 cm, respectively. For local genotypes, the bulb diameter had values between 3.47 (GR5) - 5.18 (M15) and respectively 3.41 (GH2) - 5.36 (M15), with higher limit values than those found by Panse et al. (2013) where bulb diameter varied between 2.04 and 4.33 cm. In another study, bulb diameter values varied between 2.72 and 4.70 cm (Singh et al., 2018).

Table 4. Analysis of morphological traits variability in garlic genotypes

Genotype	D.*	Bulb weight (g)		Bulb height (cm)		Bulb diameter (cm)		No. of cloves/bulb	
	Year	2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023
'Benone'	X±SD	18.41±8.28^{e}	14.60±3.32^{e}	3.55±0.48^{cd}	3.88±0.29^{ef}	3.68±0.61^{cd}	3.39±0.29^{e}	13.9±7.63^{a}	9.6±4.57^{abc}
PL1	X±SD	31.85±8.38^{dc}	41.64±14.22^{b}	4.15±0.28^{b}	4.99±0.46^{a}	4.72±0.43^{ab}	4.92±0.74^{ab}	7.2±2.04^{c}	5.8±2.04^{ce}
GH2	X±SD	19.19±5.31^{de}	19.85±8.24^{de}	3.55±0.16^{cd}	4.22±0.61^{bcdef}	3.70±0.25^{cd}	3.41±0.71^{e}	10.6±2.31^{b}	6.3±1.07^{ce}
DG3	X±SD	24.72±7.69^{bcde}	19.90±13.18^{de}	3.92±0.44^{bc}	4.03±0.71^{cdef}	3.99±0.45^{cd}	3.69±0.97^{de}	6.9±0.99^{c}	6.1±2.07^{ce}
SS4	X±SD	27.60±11.26^{bcde}	35.673±16.07^{bc}	3.68±0.44^{bc}	4.67±0.83^{abc}	4.32±0.65^{bc}	4.49±0.85^{bc}	10.7±2.62^{b}	9.4±2.01^{bc}
GR5	X±SD	16.239±7.24^{e}	18.687±7.48^{de}	3.04±0.52^{d}	3.70±0.54^{f}	3.47±0.69^{d}	3.84±0.63^{cde}	10.8±2.97^{b}	11.6±1.26^{a}
IZ6	X±SD	20.66±6.013^{cde}	20.56±7.15^{de}	3.48±0.32^{cd}	4.00±0.43^{def}	3.93±0.33^{cd}	3.79±0.4^{cde}	9±1.63^{bc}	10.3±1.25^{abc}
CN7	X±SD	24.64±6.67^{bcde}	26.34±15.73^{cde}	3.54±0.43^{cd}	4.30±0.70^{bcdef}	4.16±0.42^{bc}	4.38±0.92^{bcd}	9.3±1.33^{bc}	5.7±2.05^{ce}
PV8	X±SD	32.74±15.86^{b}	24.83±10.10^{cde}	3.82±0.59^{bc}	4.61±0.60^{abcd}	4.72±0.58^{ab}	3.86±0.58^{cde}	9.5±2.41^{bc}	6.9±1.37^{c}
BR9	X±SD	25.615±13.34^{bcde}	26.983±12.64^{cd}	3.53±0.67^{cd}	4.41±0.70^{abcde}	4.17±0.71^{bc}	4.22±0.85^{bcd}	8.9±2.28^{bc}	8.9±1.85^{c}
OR10	X±SD	25.22±14.54^{bcde}	26.60±8.99^{cde}	3.58±0.42^{c}	4.23±0.46^{bcdef}	4.12±0.82^{cd}	4.36±0.51^{bcd}	10.60±3.83^{b}	10.4±3.16^{abc}
DB13	X±SD	27.04±7.81^{b}	21.28±10.58^{cde}	3.71±0.41^{bc}	4.50±0.68^{abc}	4.24±0.51^{ab}	4.74±0.75^{cd}	11.2±1.22^{ab}	11.2±1.47^{bc}
RC12	X±SD	27.87±11.36^{bcde}	28.28±12.75^{cd}	3.57±0.53^{c}	4.25±0.73^{bcdef}	4.28±0.66^{bc}	4.35±0.66^{bcd}	10.2±1.13^{b}	9.3±1.49^{bc}
DB11	X±SD	32.70±7.39^{bcde}	26.54±11.68^{de}	3.83±0.30^{bc}	4.68±0.67^{abcde}	4.75±0.36^{bc}	4.15±0.73^{de}	11.7±2.83^{ab}	9.1±1.85^{ab}
CR14	X±SD	30.17±9.29^{bcd}	26.35±6.25^{cde}	3.87±0.42^{bc}	4.40±0.51^{abcde}	4.66±0.51^{ab}	4.40±0.4b^{cd}	11.2±2.20^{b}	6.8±1.54^{c}
M15	X±SD	49.35±22.31^{a}	49.16±17.53^{a}	4.65±1.08^{a}	4.74±0.74^{ab}	5.18±1.14^{a}	5.36±0.80^{a}	3.50±2.17^{d}	4.40±2.75^{e}

* D = Descriptors, X = mean, SD = standard deviation; according to Duncan's multiple range test, different letters in the same column meant significant differences among genotypes at $P < 0.05$

Castellanos et al. (2004) consider that the increase in the diameter of bulbs is correlated with the size of bulbs used for planting; larger bulbs lead to a higher leaf surface area index, due to the nutrients present in the bulb, and subsequently to a greater accumulation of assimilates and translocation to the bulbs, which in turn led to an increase in bulb diameter.

The number of cloves per bulb was also significantly different from genotype to genotype and year to year (Table 4). The values of morphological trait related to the number of cloves per bulb varied, for local genotypes, from 3.50 (M15) to 11.7 (DB11) and, respectively, from 4.40 (M15) to 11.6 (GR5), while for 'Benone' variety, the recorded values were 13.9 and 9.6, respectively. As for the variability in this morphological trait, Panse et al. (2013), in a study of 56 garlic genotypes, found values ranging from 16.60 to 45.60, while Baghalian et al. (2006), by analyzing 26 genotypes, recorded average values between 7.86 and 21.66.

Other authors have also identified a wide variation in the number of cloves per bulb: Atinafu et al. (2022) between 10.80 and 18.95; Singh et al. (2018) between 10.46 and 28.14. According to Desta (2021), the increase in the number of cloves is attributed to planting large-sized bulbs, respectively to a greater amount of nutrients, which promoted vigorous vegetative growth and led to increased assimilate production and translocation to the cloves. Similarly, Ahmed (2007) stated that the size of the bulb had a significant effect on the number of cloves per bulb. De Andrade (2019) considers that in the selection criteria, genotypes recording the highest number of cloves per bulb should be taken into account to increase the commercial yield of the bulbs.

Tables 5-8 present the bi-factorial analysis of all sources of variability. The genotype X environment interaction (G x E) is an analysis stemming from quantitative genetics and is used in plant breeding, reflecting genotype adaptability and stability. Phenotypic changes result from the genotype's reaction to prevailing environmental conditions. The tested genotypes exhibited different types of reactions over the two years, but it can be generally stated that an approximately equal average bulb weight (27.51-27.20 g) was obtained in both years analysed (Table 3). When considered individually, the garlic genotypes showed a range of different reactions to environmental variations. According to the results, the most significant influence on bulb weight is in the case of year ($P < 0.001$) (Table 5). Atif et al. (2019) argue that genotype, photoperiod, and temperature have a highly significant influence on bulb diameter, weight, and height.

Regarding the height of the bulb (Table 6), according to the results, the influence is very significant from a statistical point of view, for each factor (year and genotype) ($P < 0.001$).

Table 7 shows the analysis of variance for bulb diameter by genotype and year, as well as the cumulative effect of genotype and year. According to the results, the most significant influence is in the case of year and the combined influence of year x genotype on bulb diameter ($P < 0.001$).

Table 5. Bifactorial ANOVA analysis for bulb weight in garlic (Two-Way ANOVA)*

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	20931.258[a]	31	675.202	5.236	0.000
Intercept	231852.271	1	231852.271	1797.908	0.000
Year	14.003	1	14.003	.109	0.742
Genotype	19128.424	15	1275.228	9.889	0.000
Year * Genotype	1788.831	15	119.255	.925	0.537

* Type III Sum of Squares; $P < 0.001$. a - the model is significant with $P < 0.001$, which shows that the model explains or significant part of the correct total variation in the data

Table 6. Bifactorial ANOVA analysis for bulb height in garlic (Two-Way ANOVA)*

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	68.321[a]	31	2.204	6.840	0.000
Intercept	5217.904	1	5217.904	16193.805	0.000
Year	32.131	1	32.131	99.719	0.000
Genotype	31.043	15	2.070	6.423	0.000
Year * Genotype	5.147	15	.343	1.065	0.389

* Type III Sum of Squares; $P < 0.001$. a - the model is significant with $P < 0.001$, which shows that the model explains or significant part of the correct total variation in the data

Table 7. Bifactorial ANOVA analysis for bulb diameter in garlic (Two-Way ANOVA)*

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	74.848[a]	31	2.414	5.475	0.000
Intercept	5649.421	1	5649.421	12809.791	0.000
Year	.821	1	.821	1.862	0.173
Genotype	64.345	15	4.290	9.727	0.000
Year * Genotype	9.681	15	.645	1.463	0.118

* Type III Sum of Squares; $P < 0.001$. a - the model is significant with $P < 0.001$, which shows that the model explains or significant part of the correct total variation in the data

According to the results, for the number of cloves per bulb, the greatest significance lies in the combined influence of genotype and year, as well as in the action of each factor separately (genotype, year) ($P < 0.001$) (Table 8). According to the specialized literature, the growth and development of bulbs are influenced by photoperiod, temperature, and the timing of crop establishment (Atif et al., 2020). Adhering to the planting season significantly impacts plant height, bulb weight, bulb length, bulb diameter, number of cloves per bulb, and bulb yield per hectare (Shuvra et al., 2017). Crops established during the optimal season exhibit significantly greater height, a higher number of leaves, and a wider bulb diameter compared to those planted during off-season periods.

Table 8. Bifactorial ANOVA analysis for a number of cloves/bulb in garlic (Two-Way ANOVA)*

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1750.087[a]	31	56.454	8.514	0.000
Intercept	25740.313	1	25740.313	3882.075	0.000
Year	171.112	1	171.112	25.807	0.000
Genotype	1294.587	15	86.306	13.016	0.000
Year * Genotype	284.388	15	18.959	2.859	0.000

* Type III Sum of Squares; $P < 0.001$. a - the model is significant with $P < 0.001$, which shows that the model explains or significant part of the correct total variation in the data

These growth parameters suggest better vegetative development of plants and a representative accumulation of reserve substances, which is reflected in bulb size. Conversely, plants cultivated during off-season periods show reduced vegetative growth and smaller bulbs.

This could be attributed to unfavourable environmental conditions such as high temperatures or changes in photoperiod during critical growth stages (Rahman, 2023). Under conditions of high temperatures and excessive humidity, garlic may experience weight loss, and both cloves and bulbs may suffer damage, leading to a decrease in marketable garlic production (Lee et al., 2018).

CONCLUSIONS

Each analysed genotype exhibits typical characteristics. The control variety, 'Benone', was surpassed by the majority of garlic genotypes, regarding bulb weight, bulb height and bulb diameter. There were significant differences between local genotypes and the control variety. Phenotypic variations, particularly in bulb weight and number of cloves, indicate the potential for breeding superior garlic varieties with higher yields. The observed variations in bulb diameter, height, and number of cloves per bulb suggest genetic diversity and environmental influences on garlic morphology. The obtained results provide new insights into local garlic genotypes, which can be used to enhance the garlic germplasm database in Romania. Considering the superior results obtained compared to the 'Benone' variety, the analysed genotypes represent valuable sources of germplasm that can be utilized in breeding or cultivation endeavours.

REFERENCES

Ahmad, J., Wang, H., Song, J., Umer, S., Zhang, X., Yang, W., Li, X. (2023) Multivariate analysis of garlic (*Allium sativum* L.) germplasm in response to cold tolerance regimes. Crop Design, 2 (2), 100042. DOI: https://doi.org/10.1016/j.cropd.2023.100042

Ahmed, H. G., Magaji, M. D., Yakutu, A. I., Aliyu, L., Singh, A. (2007) Response of garlic (*Allium sativum* L.) to irrigation interval and clove size in semi-arid, Nigeria. DOI: https://doi.org/10.3923/jps.2007.202.208

Akan, S. (2019) Evaluation and comparison of some parameters in four garlic varieties. Journal of the Institute of Science and Technology, 9 (4), 1866-1875. DOI: https://doi.org/10.21597/jist.541783

Alam, K., Hoq, O., Uddin, S. (2016) Medicinal plant *Allium sativum*. A review. Journal of Medicinal Plant Studies, 4 (6), 72-79.

Atif, M.J., Amin, B., Ghani, M.I., Hayat, S., Ali, M., Zhang, Y., Cheng, Z. (2019) Influence of different photoperiod and temperature regimes on growth and bulb quality of garlic (*Allium sativum* L.) cultivars. Agronomy, 9 (12), 879. DOI: https://doi.org/10.3390/agronomy9120879

Atif, M.J., Amin, B., Ghani, M.I., Ali, M., Cheng, Z. (2020) Variation in morphological and quality parameters in garlic (*Allium sativum* L.) bulb influenced by different photoperiod, temperature, sowing and harvesting time. Plants, 9 (2), 155. DOI: https://doi.org/10.3390/plants9020155

Atinafu, G., Mengistu, F.G., Tewolde, F.T., Asfaw, Y., Tabor, G., Fekadu, D. (2022) Morphological characterization and evaluation of garlic (*Allium sativum* L.) accessions collected from northern highlands of Ethiopia. Results of Crop Improvement and Management Research for 2019/2020.

Badran, A.E. (2015) Comparative analysis of some garlic varieties under drought stress conditions. Journal of Agricultural Science, 7 (10), 271. DOI: https://doi.org/10.5539/jas.v7n10p271

Baghalian, K., Naghavi, M. R., Ziai, S. A., Badi, H. N. (2006) Post-planting evaluation of morphological characters and allicin content in Iranian garlic (*Allium sativum* L.) ecotypes. Scientia Horticulturae, 107 (4), 405-410. DOI: https://doi.org/10.1016/j.scienta.2005.11.008

Bandara, M. S., Krieger, K., Slinkard, A. E., Tanino, K.K. (2000) Pre-plant chilling requirements for cloving of spring-planted garlic. Canadian Journal of Plant Science, 80 (2), 379-384. DOI: https://doi.org/10.4141/p99-074

Castellanos, J.Z., Vargas-Tapia, P., Ojodeagua, J.L., Hoyos, G., Alcantar-Gonzalez, G., Mendez, F.S., Gardea, A.A. (2004) Garlic productivity and profitability as affected by seed clove size, planting density and planting method. HortScience, 39 (6), 1272-1277. DOI: https://doi.org/10.21273/hortsci.39.6.1272

Cortés, C.F., de Santa Olalla, F.M., Urrea, R.L. (2003) Production of garlic (*Allium sativum* L.) under controlled deficit irrigation in a semi-arid climate. Agricultural water management, 59 (2), 155-167. DOI: https://doi.org/10.1016/s0378-3774(02)00125-7

De Andrade, V.C., Guimarães, A.G., Firme, T.D., Costa, A., Costa, M., Lopes, T.K., Resende, F.V. (2019) Associations between morphological and agronomic characteristics in garlic crop. Horticultura Brasileira, 37, 204-209. DOI: https://doi.org/10.1590/s0102-053620190211

Desta, B., Tena, N., Amare, G. (2021) Growth and bulb yield of garlic as influenced by clove size. The Scientific World Journal, 2021. DOI: https://doi.org/10.1155/2021/7351873

Drăghici, E. M., Lagunovschi-Luchian, V. (2015) The planting period and the size of cloves influences on garlic production. AgroLife Scientific Journal, 4 (2), 9-16.

Gvozdanovic-Varga, J., Vasic, M., Cervenski, J. (2002) Variability of characteristics of garlic (*Allium sativum* L.) ecotypes. Acta Horticulturae 579, 171-175. DOI: https://doi.org/10.17660/actahortic.2002.579.26

IPGRI, ECP/GR, AVRDC (2001) Descriptors for Allium (Allium spp.). International Plant Genetic Resources Institute, Rome, Italy; European Cooperative Programme for Crop Genetic Resources Networks (ECP/GR), Asian Vegetable Research and Development Center, Taiwan.

Kıraç, H., Dalda Şekerci, A., Coşkun, Ö. F., Gülşen, O. (2022) Morphological and molecular characterization of garlic (*Allium sativum* L.) genotypes sampled from Turkey. Genetic Resources and Crop Evolution, 69 (5), 1833-1841. DOI: https://doi.org/10.1007/s10722-022-01343-4

Lee, H. J., Lee, S. G., Kim, S. K., Mun, B., Lee, J. H., Lee, H. S., Kim, C. W. (2018) Effects of combination of air temperature and soil moisture contents on growth, clove initiation, physiological disorders, and yield of garlic. Journal of Bio-Environment Control, 27 (3), 191-198. DOI: https://doi.org/10.12791/ksbec.2018.27.3.191

Mirzaei, R., Liaghati, H., Damghani, A. M. (2007) Evaluating yield quality and quantity of garlic as affected by different farming systems and garlic clones. Pakistan Journal of Biological Sciences, 10 (13), 2219-2224. DOI: https://doi.org/10.3923/pjbs.2007.2219.2224

Panse, R., Jain, P. K., Gupta, A., Sasode, D. S. (2013) Morphological variability and character association in diverse collection of garlic germplasm. African Journal of Agricultural Research, 8 (23), 2861-2869.

Petropoulos, S. A., Fernandes, Â., Ntatsi, G., Petrotos, K., Barros, L., Ferreira, I. C. (2018) Nutritional value, chemical characterization and bulb morphology of Greek garlic landraces. Molecules, 23 (2), 319. DOI: https://doi.org/10.3390/molecules23020319

Popa, P.M., Cosmulescu S. (2023) The evolution of garlic cultivation in Romania constraints and perspectives. Acta Horticulturae, 1391, 75-82. DOI: https://doi.org/10.17660/ActaHortic.2024.1391.11.

Popa, P.M., Cosmulescu, S.N., Dinu, M. (2023) Analysis of the diversity of garlic (*Allium sativum* L.) genotypes from the southwestern part of Romania based on morphological characteristics. Scientific Papers. Series B. Horticulture, 67 (1), 689-696.

Rahim, M.A., Fordham, R. (2001) Environmental manipulation for controlling bulbing in garlic. Acta Horticulturae, 555, 181-188. DOI: https://doi.org/10.17660/actahortic.2001.555.27

Rahman, M. (2023) Effects of planting time and planting system on the growth and yield of selected garlic germplasm. American Journal of Agriculture and Horticulture Innovations, 3 (07), 06-10.

Rekowska, E., Skupień, K. (2007) Influence of flat covers and sowing density on yield and chemical composition of garlic cultivated for bundle-harvest. Journal of Fruit and Ornamental Plant Research, 66 (1), 17-24.

Shuvra, J., Hossain, M., Rahman, M., Shaha, U. (2017) Effect of planting time on growth, development and yield performance of ten garlic genotypes. European academic research, 7, 3156-3176.

Singh, G., Singh, A., Shrivastav, S. P. (2018) Genetic variability, heritability and genetic advance for yield and its contributing traits in garlic (*Allium sativum* L.). International Journal of Current Microbiology and Applied Sciences, 7, 1362-72. DOI: https://doi.org/10.20546/ijcmas.2018.702.165

Tchorzewska, D., Bocianowski, J., Najda, A., Dąbrowska, A., Winiarczyk, K. (2017) Effect of environment fluctuations on biomass and allicin level in *Allium sativum* (cv. Harnas, Arkus) and *Allium ampeloprasum* var. *ampeloprasum* (GHG-L). Journal of Applied Botany and Food Quality 90, 106 – 114.

Wu, C., Wang, M., Cheng, Z., Meng, H. (2016) Response of garlic (*Allium sativum* L.) bolting and bulbing to temperature and photoperiod treatments. Biology Open, 5 (4), 507-518. DOI: https://doi.org/10.1242/bio.016444