THE MORPHOLOGICAL AND PRODUCTIVE CHARACTERIZATION OF SOME KALE GENOTYPES

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Abstract

Kale (Brassica oleracea L. convar. acephala (DC.), belongs to the Brassicaceae family and has a wide variety of uses: culinary, in landscape architecture, in traditional medicine, or as a plant with allelopathic potential through plant residues introduced into the soil releases glycosinolates that have a nematocidal effect. In Europe there are numerous genotypes introduced into the culture. The aim of this study was to analyze the morphological and production characters of an assortment of kale genotypes grown in South-West Region of Romania. The morphological character with the highest variability was plant height, which varied from 45 cm to 74.2 cm. The leaf rosette diameter registered the lowest value of 57 cm and the highest was 70.4 cm. The lenght and width of the leaf varied from 35.4 cm to 45.4 cm and respectively, from 9.05 cm to 16.47 cm, while the average weight of fresh leaves raged between 28.98 g and 56,15 g. All previously mentioned characters influenced useful production of leafy cabbage, which registered an amplitude of variation between 2.23 kg/m2 and 4.90 kg/m2. The morphological and productivity variability registered from within the analyzed genotypes, indicates a high diversity and a degree off their adaptability for cultivation in extensive crops in the SouthWestern area of Romania.

Key words: kale, genotyp, variability

INTRODUCTION

Leaf cabbage, also known as kale (*Brassica oleracea* L. convar. *acephala* (DC.), *Brassicaceae* family, is a vegetable species that has an important place in culinary preparations and the diet of the population in Europe, Asia and America. Kale is a vegetable that, along with other brassicas belonging to the Brassica genus, is characterized by a rich rosette of leaves. Due to its good tolerance to temperature fluctuations caused by climate change in recent decades, kale is a popular crop among European farmers (Šamec et al., 2018). Fresh leaves can be used as juice, prepared either separately or mixed with the juice of other vegetables such as carrots and celery, or included in numerous diets in the form of salad or soup. Also, some studies suggets the potential of cabbage consumption to alleviate oxidative stress and inflamation (Rokayya, 2013).

Leaf cabbage is one of the healthiest vegetables due to its content in antioxidants with a role in protecting the cells of the human body from free radicals. Acikgoz (2011) stated that leaf cabbage can be consumed as a selection of fundamental nutrients and for this it is important to consider that harvesting must be done at maturity.

According to the availabe literature, the choice of crucifers in the diet may be based on availability and consumer preferences

(Šamec et al., 2018). According to Błażewicz-Woźniak et al., (2021) the nutritional value of kale is influenced by the content in mineral components, namely colored leaves are more abundant in nitrogen, phosphorus, potassium and magnesium, while green leaves have higher content in calcium and sulfur. Moreover, it is also widely used in traditional medicine for the treatment of rheumatism, liver or bone diseases, anemia (Pipan et al., 2024; Thavarajah et al., 2016). It is considered an ideal source of vitamins, essential minerals and fatty acids (Pathirana et al., 2017). Due to this properties, pharmaceutical companies have launched nutraceutical products made from kale. In addition to these benefits of leaves, the seeds can also be used for oil, by mixing the crude oil with some food products (e.g. bread and cakes) (Ayaz et al., 2006).

Brassica crops also have allelopathic potential through plant residues that can be introduced into the soil and through the release of glycosinolates have a nematocidal effect. This advantage will reduce the environmental hazard caused by chemical pollution, which contributes to acheiving the goal of sustainable culture without compromising food safety (Prendes-Rodríguez et al., 2022).

Leaf cabbage cand be used in landscape architecture, for the implementation of the „edible landscape" system, because the variability of varieties and hybrids available on the market offers the possibility of creating beautiful landscape arrangements.

Leaf cabbage lends itself very well to cultivation in Romania (Balcău et al., 2013), but respecting the establishment period of the crop, because environmental factors can negatively influence production.

The introduction of new vegetables on the Romanian market can have multiple advantages through good profits for producers, possibilities of diversifying the population's diet, the introduction of vegetables with high biological value into diet.

In Romania, kale is cultivated sporadically and for its promotion in the culture it is necessary to popularize the species among growers (Cărbunar et al., 2021).

Lately, genotypes with vigorous and strongly wrinkled leaves have been obtained through breeding. This species, due to its resistance to low temperatures, can be cultivated in the spring and harvesting can take place during the summer and until late autumn or even during winter. Leaves can be harvested 4-6 weeks after planting, depending on the desired size. These are harvested by removing them from the base of the stem, which promotes the growth of new ones and a consequently higher yield.

There is a constant concern of breeders to obtain new cultivars of leafy cabbage. For this reason, the cultivars introduced into the culture must be very well evaluated to observe their behaviour in the local climatic conditions. An essential step in describing the available genetic resources and ensuring their effective use in breeding programs is the characterization of the genetic diversity of the available germplasm (Pipan et al., 2024).

The purpose of this study was to know the behaviour of some leaf cabbage genotypes in the conditions of South-West Romania and the promotion of these in culture.

MATERIALS AND METHODS

The experiment was established in the didactic field of Faculty of Horticulture, University of Craiova, on a preluvosoil in the period 2022-2023 and followed the behaviour of seven leaf cabbage genotypes. The characterization of the leaf cabbage genotypes is shown in table 1. For establishing the culture, seedlings were produced by sowing on February 25 in alveolar pallets filled with peat, in a heated greenhouse. At plating, the seedlings were 50 days old.

Table1. General characterization of leafy cabbage genotypes

Genotype	Genotype characterization:	
	The appearance of leaves	Characteristics
G1-"Nero Di Toscana"	Elongated leaves, blue-green in color with an embossed surface and gathered at the top of the stem in a vertical position	The plant is also decorative in general appearance like a palm tree.
G2-"Scarlet"	Strongly wrinkled, purple leaves	Frezing temperatures intensify the color into a very attractive blue-purple.
G3-"Lerchenzungen"	Elongated leaves, strongly wrinkled and slightly pedunculated, having a light green color.	The variety is medium tall.
G4-"Halbhoher"	Oval, wrinkled, dark green leaves	The variety is semidwarf.
G5-"Westlander Halbhoher"	Oval leaves, stronlgy wrinkled, having a dark green color.	The variety is medium tall. It has good frost resistance. Iti is laso harvested after light frosts.
G6- "Jarmuz"	Wrinkled leaves, having grey-green color.	Dwarf size and well-developed leaf apparatus
G7-"Cadet"	Strongly wrinkled leaves, having a dark green color.	The variety has a high tall and a well developed leaf apparatus.

The seedlings were planted in the filed in April 25. Planting distances were 80 cm between rows and 40 cm between plants per row, resulting 31250 plants/ha.

In order to acheive the proposed objectives, observations and biometric determinations were made regarding the morphological and productivity characters, when the plants had an optimal development: plant height (cm); stem diameter (cm); leaf length (cm); leaf width (by measuring the transverse diameter); petiole length (cm); the number of leaves;

- the diameter of the leaf rosette (cm); the average weight of the leaf (g); production (kg/m^2).

Statistical analysis.

The data obtained were statistically analyzed by means, standard deviation (SD) and coefficient of variation (CV) descriptive analysis. In order to compare the genotypes each with each other, the method of multiple comparisons and the t-test was used.

RESULTS AND DISCUSSIONS

Agromorphological traits can be controlled at genetic level, but their variation could be strongly influenced by environmental factors and cultural practices. Leaf cabbage genotypes show great variability in leaf size and type.

Regarding the variability of the main morphological and productivity characters in the studied leaf cabbage cultivars, it is found that they have valuable genetic and productivity characteristics. Thus, regarding the height of the plant, it varied according to the genotype, and on average, it was between 45 cm for „Jarmuz" genotype and 74.2 cm for „Cadet" genotype. Nero di Toscana, Halbhoher and Westlander halbhoher genotypes also have a tall plant size. The coefficient of variation was ≤ 9% for all genotypes, indicating a little variability for this character (Table 2). In some scientific papers, authors have reported a large variability of plant height depending on region, environmental conditions and genotype. Thus, in studies carried out in Romania, authors reported different heights of leafy cabbage plants, depending on the planting period, between 38.36 cm and 59.21 cm (Balcău et al., 2013). According to Korus (2010) in a study conducted in Poland, plant height varied from 66 cm to 115 cm, and Cartea et al. (2002), in their research in Spain on the characterization of 15 kale populations, reported a range of variation in plant height between 164.2-214.2 cm.

Stem diameter was determined by measuring the circumference at the soil surface. Thus, values between 3.37 cm and 4.14 cm were recorded, indicating good plant vigor to maintain an upright position. Regarding the values of the coefficient of variability, it was less than 10%, indicating a low variability, with the exception of the Lerchenzungen genotype, which registered 10.9% (Table 2). Regarding the diameter of the plant (leaf rosette) in the genotypes studied, it recorded a range of variation from 48.6 cm (Nero di Toscana) to 70.4 cm (Cadet). The size of this character emphasizes the decorative aspect of the genotype, in addition to the leaves with a specific appearance and color. It can be stated that the diameter of the plant (leaf rosette) varied significantly between the studied genotypes and based on this character genotypes with landscape value can be selected. In the study conducted by Malik et al. (2024) on 62 accessions of kale reported the diameter of the leaf rosette between 27.86 and 67.24 cm, and Pipan et al. (2024) reported the diameter of the plant up to 57.97 cm.

Table 2. Variability of the stem in the studied genotypes

Genotypes	Plant Height (cm)		Stem diameter (cm)		Leaf rosette diameter (cm)	
	X±SD	CV%	X±SD	CV%	X±SD	CV%
G1-”Nero Di Toscana”	68,6±6.19	9.0	3.84±0.21	5.4	48.6±6.07	12.48
G2-”Scarlet”	73,2±3.27	4.5	3.42±0.19	5.6	68±1.22	1.80
G3-”Lerchenzungen”	67.0 ± 4.06	6.1	3.5±0.38	10.9	70±2.55	3.64
G4-”Halbhoher”	60.8 ± 1.64	2.7	3.37±0.17	5.1	57±2.00	3.51
G5-”Westlander Halbhoher”	68.4 ± 2.41	3.5	3.58±0.28	7.8	63.8±2.77	4.35
G6- ”Jarmuz”	45± 2.92	6.5	3.78±0.38	10.0	62.8±2.28	3.63
G7-”Cadet”	74.2± 2.95	4.0	4.14±0.24	5.8	70.4±8.5	12.08

The size of the leaves is an important character in the landscape structure of the land, in the growth and development of the genotype. The length of the leaves in most genotypes studied was between 35.5 cm and 45.4 cm, and the coefficient of variability was between 5.16 and 9.24 %, indicating an uniform variability of this character in all genotypes. The leaf width ranged from 12.6 cm to 17.86 cm and the coefficient of variation ranged from 5.16 to 17.41%, which means that there is variability within each genotype. Regarding the length of the petiole, values between 9.5 cm and 11.0 cm were recorded, and the coefficient of variability had values between 4.19 and 15.15% (Table 3).

In some studies, the length of the leaves was reported between 31–40 cm, and the width between 16–21 cm (Pipan et al., 2024), and Malik et al. (2024) reported for the characterization of 62 accessions of kale, the average length of the leaf of 20.10 cm, the average width of 14.41 cm and the average length of the petiole of 11.65 cm. It can be appreciated that the length and width of the leaves are greatly influenced by the genotype.

In a study by Balkaya and Yanmaz (2005) in the Black Sea region of Turkey on 22 kale genotypes, the following leaf sizes were reported: 15.9–21.9 cm for length, 10.4–13.2 cm for width and 0.26–0.35 mm for its thickness. The appearance of the leaves, with smooth or slightly indented edges, the wavy or roughened surface can influence consumer preferences. Also, the position of the median rib, its thickness and color can influence the quality of the leaves and the attractiveness for consumption (Balkaya and Yanmaz, 2005). For this reason, leaves with a smaller, thin main rib and a green color are preferred.

Most of the genotypes presented the color of the leaves of different shades, from light green to blue-green, and mostly having the surface of the limb wrinkled. Wrinkling is considered a sign of quality, and those with medium or small ribs are usually preferred (Khan et al., 2010). According to Pipan et al. (2024), the high variation in morphological characters could be the result of cross-pollination between populations, the influence of the light spectrum or environmental conditions.

Table 3. Variability of the leaf in the studied genotypes

Genotype	Leaf length (cm)		Leaf width (cm)		Petiole length (cm)	
	X±SD	CV%	X±SD	CV%	X±SD	CV%
G1-"Nero Di Toscana"	45.4±2.7	5.95	12.6±1.14	9.05	10.7±1.23	11.49
G2-"Scarlet"	36.2±3.35	9.24	15.86±1.97	12.45	11±1.08	9.8
G3- "Lerchenzungen"	42.1±2.33	5.54	17.86±0.86	4.84	9.5±1.44	15.15
G4-"Halbhoher"	36.6±1.98	5.16	17.64±1.15	6.55	9.8±1.48	15.10
G5-"Westlander Halbhoher"	41.9±3.11	7.41	13.08±1.04	7.97	10.4±0.66	6.34
G6- "Jarmuz"	37.1±2.41	6.49	16.4±2.7	16.47	10.3±0.79	7.66
G7-"Cadet"	35.4±1.99	5.61	14.6±1.58	10.82	10.5±0.44	4.19

Production is a particularly complex characteristic and depends on the formation and development of productivity elements, which are characteristics fixed in the hereditary base of cultivars, but also influenced by their interaction with environmental conditions. Climate change has become a serious threat and affects many aspects of the life of organisms in all regions of the world (Iancu et al., 2024).

Leaf cabbage is a less demanding species in terms of soil and atmospheric moisture, compared to other brassicas. However, in conditions of water stress, the leaves remain small and with very low density.

The average number of leaves per plant in the kale genotypes studied varied between 24 and 29.33, and the coefficient of variability between 5.18 and 7.20, indicating a low variability of this character. Regarding the average weight of the kale leaves, values were recorded from 28.98 g for the Cadet genotype to 46.5 g for "Lerchenzungen", and the coefficient of variability had small values, indicating a homogeneous variability of this character (Table 4.).

Mean production values by variants were subjected to multiple comparisons analysis by t-test to determine the degree of significance between variants. In the present study, production ranged from 2.47 kg/m^2 to 4.90 kg/m^2 (Table 5). The lowest production was registered for the genotype G7- Cadet and the highest for G3- "Lerchenzungen". Production results can be influenced by plant height, the number of leaves formed and their weight.

Table 4. Variability of productivity elements for the studied genotypes

Genotype	Average number of leaves per plant		Average leaf weight (g)	
	X±SD	CV%	X±SD	CV%
G1-"Nero Di Toscana"	28.67 ± 1.53	5.33	45.15 ± 1.04	8.85
G2-"Scarlet"	27.9 ± 1.89	6.67	34.53 ± 3.51	10.16
G3- "Lerchenzungen"	29.1 ± 2.07	6.89	46.5 ± 3.68	7.92
G4-"Halbhoher"	25.33 ± 1.54	6.07	44.74 ± 5.10	11.40
G5-"Westlander Halbhoher"	25.67 ± 2.08	8.10	33.96 ± 3.15	9.29
G6- "Jarmuz"	24 ± 1.73	7.20	41.08 ± 4.00	9.74
G7-"Cadet"	29.33 ± 1.52	5.18	28.98 ± 2.38	8.21

The production ranking indicates the following order: G3≥G1≥G6≥G5≥G2≥G7 From the results obtained regarding the production, a small variability of this character can be observed in the studied genotypes, only in four cases the differences are significant from the total of 21 groups (Table 5).

Table 5. Multiple comparison analysis of kale leaf production

Variant/ clasification	Production (kg/m^2)	The difference from the version on the ranking:					
		G1	**G6**	**G5**	**G2**	**G7**	**G4**
G3	4.90	1.20	1.75	1.91*	2.01*	2.47*	2.67**
G1	3.70		0.55	0.71	0.81	1.27	1.47
G6	3.15			0.16	0.26	0.72	0.92
G5	2.99				0.1	0.56	0.76
G2	2.89					0.46	0.66
G7	2.47						0.20

Growing conditions and genotype are the predominant factors influencing production. The introduction of new genotypes into the culture, with high yields and increased resistance to unfavorable factors, causes an increase in their requirements for fertilization (Iancu et al., 2019). The quality of the soil and the introduction of irrigation and an appropriate fertilization regimen has a significantly positive effect on crop production (Niţu et al., 2024; Balan et al., 2024).

Choosing the most suitable cultivar for each growing area, plays a crucial role in obtaining high and quality yields (Dunăreanu and Bonea, 2022; Dunăreanu et al., 2023). Balcău (2013), in a study on the behavior, growth and development of leafy cabbage plants, in the climatic conditions of the Transylvanian Plateau (Romania), reported kale yields from 2.84 to 4.69 kg/m^2, and Korus (2010) from 5.13 to 9.32 kg/m^2. According to other authors, the weight of the leaves depends on the season of cultivation. Thus, Daccache et al. (2021) reported a marketable yield of 0.91 kg/plant and 4.97 kg m^2 for the autumn season and 0.56 kg/plant and 3.26 kg m^2 in the spring season.

CONCLUSIONS

Cultivation of an assortment of kale genotypes in the South-West of Romania highlighted the adaptability of this species and the possibility of obtaining quantitatively high productions.

Considering that it has lower temperature requirements, it can ensure the consumption of fresh vegetables for a long period of time, which contributes to the diversification of the diet.

Kale can be used as a niche crop for small farmers, or for the practice of ecological agriculture due to its allelopathic potential and good adaptability to environmental conditions.

This variety of cabbage has decorative value, due to its morphological characteristics, through the growth of the plant, through the color, appearance and arrangement of the leaves.

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