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The influence of the cultivar and the cultivation technology on the yield of leaf cabbage (*Brassica oleracea* var. *palmifolia*)

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Abstract
The production of vegetables in the countries of the European Union increased by more than 34% (1970-2020) in the large producing countries, by increasing the yield, in the conditions of the decrease of cultivated areas. Kale is a leafy vegetable which tolerates low temperatures, being feasible for both in field and protected cultivation in Transylvania's climate conditions. The aim of this research was to evaluate the production of two cultivars of kale ('Red Siberian', 'Black Tuscany'), influenced by plant height and facial fertilization, produced in solar. The two kale cultivars were cultivated in 2023 year in a high tunnel, in Colina Farms, which is located in Băbuțiu village – Cluj County. Genotype is of great importance in achieving high production. The most valuable variety, in terms of total production, turned out to be Siberian Red, with an average production per experience of 6.9 kg/m^2. Following the unilateral analysis of fertilization on production, it is observed that the plants of the organically fertilized variants achieve a lower production by 1.35 kg/m^2, compared to chemical fertilization (7.09 kg/m^2). The production of green cabbage in the solar system was high in the conditions of Transylvania, as a result a possible source of income for farmers, having the advantage of a simple culture technology.

Key words: leaf cabbage, production, high tunnel, fertilization

Introduction

The production of vegetables in the countries of the European Union increased by more than 34% (1970-2020) in the large producing countries, by increasing the yield, in the conditions of the decrease of cultivated areas. [5]. As far as kale is concerned, there is no precise scientific data on total production and cultivated area. According to 2021 USDA publications, 3400 hectares of kale were cultivated in the United States [16]. In the USA in 2017, 56,245 t of leafy cabbage were sold, most of which were certified organic [5], in 2020 the production was 89,389 t [5].

As for leafy cabbage, in our country it is grown on small areas, in our own gardens, without statistical records [8]. In 2012, under the conditions of Transylvania, 2.85 kg/m2 were obtained [3], the values can be influenced by several factors: the planting season, the hybrid used, the climatic conditions specific to the area, the administered fertilizers. Thus, Drost et. al., 2010 [4], Balasa, 1973 [2], Parvu, 2005 [12] and Indrea, 2009 [8], shows that the production of leafy cabbage can vary between 4.6 t/ha and even 25 t/ha.

The stress and challenges of everyday life are at the origin of several diseases such as heart related diseases, abnormal cell growth, uncontrolled multiplication leading to cancer and neurological disorders. Food plays an essential role in the anticipation of the aforementioned diseases. Green vegetables are important in the diet because of compounds, especially vitamins and minerals that protect cells [13].

Epidemiological studies have found a strong link between *Brassicaceae* consumption and low cancer incidence. Different types of leafy vegetables such as kale can reduce the incidence of chronic diseases such as coronary heart disease, cancer and stroke [10].

Vitamins are organic compounds that are obtained from various food sources [17]. Kale is a known rich source of vitamins [18]. Also, Kale is a source of water-soluble vitamins (WSV) (group B and C) as well as fat-soluble vitamins (FSV) (complex A, E, D and K). The water-soluble ones are easily assimilated by the body [15].

Some researchers have shown that green vegetables prevent various diseases (metabolic disorders, Alzheimer's disease and asthma). Leafy vegetables, especially kale, play a major role in the metabolism of the

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human body. Previous studies suggest that a diet rich in greens is linked to a lower incidence of type two diabetes [1, 14].
Other health benefits associated with a regular intake of kale include antigenotoxic activity [6], anticancer activity, and protection of the cardiovascular system and gastrointestinal tract [11].

Material and Method

In 2023, a three-factor experiment was installed in the Colina Farms located in the village of Băbutiu, Vultureni, Cluj county. A 450 m^2 solar plot was used, the area occupied by the experiment was 252 m^2, and the surface of the experimental plot was 21 m^2. The experimental cultures were placed according to the method of subdivided blocks, with randomized plots (Figure 1), in the following variants:
Factor A – phase fertilization with:

a1 chemical (complex 20:20:20) – manufacturer Topfert, application dose recommended by the manufacturer

150kg/ha at each fertilization

a2 organic (Fertildung 4:4:4) - manufacturer Fomet, application dose recommended by the manufacturer,

750 kg/ha, at each phase fertilization

Factor B – density with:

b1 67,000 plants/ha (100+50/30 cm)
b2 50,000 plants/ha (100+50/40 cm)
b3 100,000 plants/ha (100+50/20 cm)

Factor C – the variety with:

c1 'Black Tuscany' (NT) – (Figure 2)
c2 'Red Siberian' (RS) – (Figure 3)

a2	c2	b1	b2	b3	b2	b3	b1	b3	b2	b1
	c1	b1	b2	b3	b2	b3	b1	b3	b2	b1
a1	c2	b1	b2	b3	b2	b3	b1	b3	b2	b1
	c1	b1	b2	b3	b2	b3	b1	b3	b2	b1

Figure 1. Experience location sketch.

Figure 2. cv. 'Black Tuscany' (NT)
Producer: Semiorto Sementi

Figure 3. cv. 'Red Siberian' (RS)
Producer: Kiepenkerl

The experience was organized in three rehearsals, the surface of each rehearsal being 7 m^2. Ensuring the different thickness of the plants was achieved by planting them at a distance of 100+50cm between rows and at a distance of 30 cm between plants per row for 67,000 plants/ha, 40 cm between plants per row for 50,000 plants/ha and 20 cm between plants in a row for 100,000 plants/ha.

The morphological characters of cabbage leaves are made up of petiole length, leaf blade length, leaf blade width, blade mass and total leaf mass.

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Results and Discussions

Table 1 shows the vegetative growth of plants. At planting, the 'Black Tuscany' variety showed an average of 3.3 true leaves, while the 'Red Siberian' variety had an average of 3.9 true leaves. The height of the plant was 9.37 cm for the 'Black Tuscany' variety, and the 'Red Siberian' variety recorded heights of 9.36 cm. The diameter of the plot at planting was 0.125 cm for 'Black Tuscany' and 0.148 cm for 'Red Siberian' respectively.

Table 1. Vegetative growth of plants

Period	Variety	Density			Density			Density		
		100,000 plants / ha			67,000 plants / ha			50,000 plants / ha		
		Leaf	Height [cm]	Leaf bundle diameter [cm]	Leaf	Height [cm]	Leaf bundle diameter [cm]	Leaf	Height [cm]	Leaf bundle diameter [cm]
At plating	'Black Tuscany'	3.30	9.37	0.121	3.30	9.37	0.121	3.30	9.37	0.121
14 days		6.55	20.96	0.407	6.25	17.54	0.315	7.10	22.58	0.346
21 days		9.45	27.12	0.510	6.95	26.25	0.495	7.70	27.75	0.504
30 days		9.55	31.35	0.680	8.85	36.18	0.761	9.20	36.80	0.771
At planting	'Red Siberian'	3.90	9.36	0.148	3.90	9.36	0.148	3.90	9.36	0.148
14 days		7.00	19.33	0.467	5.30	20.13	0.392	7.00	23.73	0.446
21 days		7.45	26.20	0.551	7.05	28.99	0.660	8.05	31.44	0.768
30 days		7.50	35.73	0.840	8.40	38.17	1.104	10.20	43.39	1.206

Regarding the measurements at 14 days, 21 days and 30 days respectively, for the plot of 100,000 plants/ha the number of leaves for the 'Black Tuscany' variety were 6.5, 9.45 and 9.55 leaves respectively, while the variety 'Red Siberian' recorded a lower number of fruits/plant with an actual of 7.5 leaves at the end of 30 days. For the cultivar 'Black Tuscany', the highest values of the number of leaves were obtained at the plot of 100,000 plants/ha, while the lowest values were obtained at the plot of 67,000 plants/ha. The 'Red Siberian' cultivar obtained the highest number of leaves in the first 30 days at the plot of 50,000 plants/ha with an average of 10.2.

The height of the plants in the first 30 days recorded maximum values of 43.39 cm for the 'Red Siberian' variety at 50,000 plants/ha, and for the 'Black Tuscany' variety, values of 36.8 cm were also recorded at 50,000 plants/ha. The minimum values were recorded for the 'Black Tuscany' variety at the plot of 100,000 plants/ha with values of 31.35 cm, while the 'Red Siberian' variety recorded values of 35.73 cm also for the plot of 100,000 plants/ha.

The diameter of the parcel had maximum values of 1.20 cm for the 'Red Siberian' variety with a plot of 50,000 plants/ha, and the 'Black Tuscany' variety had a maximum value of 0.77 cm, also with a plot of 50,000 plants/ha. The minimum values were recorded by both varieties at the plot of 100,000 plants/ha.

Table 2. presents the biometric measurements starting from the first day of fertilization, 45 days after fertilization and 90 days after fertilization, respectively.

Table 2. Leaf biometric measurements

Period	Variety	100,000 pl/ha					67,000 pl/ha					50,000 pl/ha				
		Petiole length [cm]	Limb length [cm]	Limb width [cm]	Leaf mass [g]	Limb mass [g]	Petiole length [cm]	Limb length [cm]	Limb width [cm]	Leaf mass [g]	Limb mass [g]	Petiole length [cm]	Limb length [cm]	Limb width [cm]	Leaf mass [g]	Limb mass [g]
Fertilization	'Black Tuscany'	9.51	20.89	10.46	11.86	8.71	11.2	21.07	10.76	14.43	9.57	11.87	21.33	11.61	15.71	11.14
After 45 days		10.5	24.3	14.7	16.7	11.45	12.81	24.12	12.6	18.6	13.56	14.2	24.74	13.45	17.8	13.46
After 90 days		11.97	26.7	15.6	18.56	12.6	13.64	26.74	16.7	20.4	15.4	13.9	25.87	14.97	19.64	14.95
Fertilization		15.33	20.86	16.7	21.14	12.57	16.9	22.66	17.1	26.71	16.0	17.61	23.27	18.03	29.57	17.43

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After 45 days	'Red Siberian'	18.95	26.7	25.6	30.25	19.8	19.7	25.6	22.47	31.4	19.6	18.6	24.8	24.3	32.14	19.95
After 90 days		19.2	28.6	27.8	34.9	20.4	19.8	25.47	24.12	34.1	20.4	19.4	24.0	25.1	33.7	20.3

The largest leaf lengths for the 'Black Tuscany' variety were obtained at the plot of 67,000 plants/ha, with average values of 26.74 cm, and for the 'Red Siberian' variety, values of 28.6 cm were obtained at the plot of 100,000 plants/ha. The maximum weight of a leaf was recorded for the 'Red Siberian' variety at the plot of 67,000 plants/ha with values of 34.9 g, at the same plot and for the 'Black Tuscany' variety, the maximum value of 20.4 g/leaf was obtained.

The measurements regarding the height and diameter of the plant are presented in Table 3., the maximum values for the height were recorded by the chemically fertilized Red Siberian variety at the plot of 67,000 plants/ha, with values of 86.7 cm; while the 'Black Tuscany' variety had the maximum values at the plot of 50,000 plants/ha chemically fertilized with a value of 82 cm.

Table 3. Results regarding plant height and diameter measurements at different vegetation periods

Period	Variety	Fertilization	100,000 plants / ha		67,000 plants / ha		50,000 plants / ha	
			Height [cm]	Diameter [cm]	Height [cm]	Diameter [cm]	Height [cm]	Diameter [cm]
45 days	'Black Tuscany'	Organic	36.0	37.0	40.5	37.5	40.3	39.3
		Chemical	51.3	38.5	46.0	39.3	50.8	40.5
120 days		Organic	64.7	51.7	73.7	48.7	59.7	47.0
		Chemical	71.3	55.7	78.0	61.7	82.0	63.7
45 days	'Red Siberian'	Organic	47.3	39.0	48.5	40.5	45.5	36.3
		Chemical	52.0	59.8	50.3	56.8	52.5	60.3
120 days		Organic	45.0	59.0	68.7	61.7	59.3	69.0
		Chemical	82.0	65.7	86.7	71.3	64.7	57.7

Plant diameter recorded maximum values of 65.7 cm for the chemically fertilized 'Red Siberian' variety at 100,000 plants/ha; while the 'Black Tuscany' variety had the highest values at the plot of 50,000 plants/ha, chemically fertilized with values of 63.7 cm.

Genotype is of great importance in achieving high production. The most valuable variety, from the point of view of total production, turned out to be 'Red Siberian', with an average production per experience of 6.9 kg/m^2 (Table 4), with an increase of 16.3% , significantly different from the control ('Black Tuscany').

Table 4. Unilateral influence of cultivar on yield in leaf cabbage

Variety	Total production		Differences ± [kg/m^2]	Signification
	[kg/m^2]	Relative values [%]		
'Black Tuscany'	5.94	100.0	0.00	Avg.
'Red Siberian'	6.90	116.3	0.97	**
LSD (p 5 %)			0.56	
LSD (p 1 %)			0.79	
LSD (p 0.1 %)			1.11	

In table 5, the unilateral influence of phasial fertilization on production was analyzed. On average, based on experience, it is observed that the plants of the organically fertilized variants achieve a lower production by 1.35 kg/m^2, a significant negative difference compared to chemical fertilization.

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Table 5. Unilateral influence of fertilization on yield in leaf cabbage

Fertilization	Total production		Differences ± [kg/m^2]	Signification
	[kg/m^2]	Relative values [%]		
Chemical	7.09	100	0,00	Avg.
Organic	5.75	81.0	-1.35	0
LSD (p 5%)			1.27	
LSD (p 1%)			2.93	
LSD (p 0.1%)			9.32	

Under the unilateral influence of plant density on production, it can be observed that the highest productions on average per experience were obtained at the thickness of 67,000 plants/ha, without statistically ensured differences compared to the other densyties (Table 6.)

Table 6. Unilateral influence of thinning on yield in leafy cabbage

Density	Total production		Differences ± [kg/m^2]	Signification
	[kg/m^2]	Relative values [%]		
67,000 plants/ha	6.79	100	0.00	Avg.
50,000 plants/ha	6.39	94.1	-0.40	-
100,000 plants/ha	6.08	89.5	0.71	-
LSD (p 5%)			0.98	
LSD (p 1%)			1.42	
LSD (p 0.1%)			2.13	

The combined influence of two studied factors: variety and fertilization, are analyzed in Table 7.

Table 7. Influence of cultivar and fertilization on yield in leaf cabbage

Variety	Fertilization	Total production		Differences ± [kg/m^2]	Signification
		[kg/m^2]	Relative values [%]		
'Black Tuscany'	Chemical	6.49	100.00	0.00	Avg.
'Red Siberian'	Chemical	7.70	118.60	1.21	**
'Black Tuscany'	Organic	5.38	100.00	0.00	Avg.
'Red Siberian'	Organic	6.11	113.50	0.72	-
LSD (p 5%)				0.79	
LSD (p 1%)				1.11	
LSD (p 0.1%)				1.57	

In the case of facial fertilization with organic fertilizer, no statistically guaranteed production differences can be found between the two varieties, 'Red Siberian' and 'Black Tuscany'. At facial fertilization with chemical fertilizer, the 'Red Siberian' variety recorded a distinctly significant increase in production of 18.6%, compared to the 'Black Tuscany' variety. Table 8 presents the combined influence of the factors on the production of cabbage for leaves.

Table 8. The combined influence of the factors on the production of cabbage for leaves

Fertilization	Plant density	Variety	Total production		Differences ± [kg/m^2]	Signification
			[kg/m^2]	Relative values [%]		
Chemical	67,000 plants/ha	'Black Tuscany'	6.97	100.00	0.00	Control
Chemical	67,000 plants/ha	'Red Siberian'	7.22	103.50	0.25	-

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Chemical	50,000 plants/ha	'Black Tuscany'	6.32	90.70	-0.65	-
Chemical	50,000 plants/ha	'Red Siberian'	7.83	112.30	0.89	-
Chemical	100,000 plants/ha	'Black Tuscany'	6.17	88.50	-0.80	-
Chemical	100,000 plants/ha	'Red Siberian'	8.04	115.30	1.07	-
Organic	67,000 plants/ha	'Black Tuscany'	6.38	91.50	-0.59	-
Organic	67,000 plants/ha	'Red Siberian'	6.59	94.50	-0.38	-
Organic	50,000 plants/ha	'Black Tuscany'	4.92	70.60	-2.05	oo
Organic	50,000 plants/ha	'Red Siberian'	6.49	93.10	-0.48	-
Organic	100,000 plants/ha	'Black Tuscany'	4.85	69.60	-2.12	oo
Organic	100,000 plants/ha	'Red Siberian'	5.24	75.20	-1.73	o

LSD (p 5%) 1.37
LSD (p 1%) 1.93
LSD (p 0.1%) 2.72

Analyzing the combined influence of the three studied factors on the production of leaves, it is found that the chemically fertilized 'Red Siberian' variety, at the plot of 100,000 plants/ha, achieves the highest production of 8.04 kg/m^2, without ensured statistical differences in production compared to the control, the 'Black Tuscany' variety, chemically fertilized, at a plant density of 67,000 plants/ha.

To highlight the differences in production in leaf cabbage, the statistical interpretation was carried out by the Duncan test (Table 9).

Table 9. Average yields [kg/m^2] of cabbage for leaves

Variety	Fertilization	Plant density	Production [kg/m^2]	Signification
'Black Tuscany'	Organic	100,000 plants/ha	4.85	F
'Black Tuscany'	Organic	50,000 plants/ha	4.92	EF
'Red Siberian'	Organic	100,000 plants/ha	5.24	DEF
'Black Tuscany'	Chemical	100,000 plants/ha	6.17	DEF
'Black Tuscany'	Chemical	50,000 plants/ha	6.32	CDEF
'Black Tuscany'	Organic	67,000 plants/ha	6.38	CDE
'Red Siberian'	Organic	50,000 plants/ha	6.49	BCDE
'Red Siberian'	Organic	67,000 plants/ha	6.59	ABCDE
'Black Tuscany'	Chemical	67,000 plants/ha	6.97	ABCD
'Red Siberian'	Chemical	67,000 plants/ha	7.22	ABC
'Red Siberian'	Chemical	50,000 plants/ha	7.83	AB
'Red Siberian'	Chemical	100,000 plants/ha	8.04	A

SD 1.37-1.56

Conclusions

Following the experiences carried out in 2023, in the town of Băbutiu, with kale, good production can be noted in solar conditions. Being a vegetable species with a relatively simple production technology and good resistance to diseases and pests, it has potential for widespread use by farmers. Due to its resistance to cold, leafy cabbage can be used in cultivation all year round, cultivated in solariums or greenhouses during the winter can be an important source of minerals and vitamins with real health-improving benefits.

The highest production 8.04 kg/m^2 was registered at Red Siberian variety, with chemical fertilization at 100,000 plants/ha planting density.

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