

Research Regarding the Planting Density Influence upon the Growth, Development and Yield of Chinese Cabbage (*Brassica campestris* var. *pekinensis* (Lour.) Olson) in Early Protected Crops in Transylvanian Tableland Specific Conditions

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Abstract. In the spring of 2011 a research was organized in the experimental field which belongs to the Vegetable Growing Department, from Faculty of Horticulture of the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. The main purpose of this experiment was the study of two varieties of Chinese cabbage (*Brassica campestris* var. *pekinensis* (Lour.) Olson) planted at different densities in early crops from polyethylene tunnels in Transylvanian Tableland specific conditions. In this research were used two varieties ('Vitimo F1' and 'Granat'), and three planting densities (100 thousand plants/ha, 80 thousand plants/ha and 66.7 thousand plants/ha). The results showed that best results were obtained at a density of 80 thousand plants/ha, thereby the highest weight of plants was recorded at 'Vitimo F1', while the heaviest cabbage heads were measured at 'Granat' variety, planted at the same density. There were no bolted plants at 'Vitimo F1' hybrid, while at 'Granat' variety the bolting percentage reached even the value of 35%. The highest yield, 97.47 t/ha, was registered at 'Granat' variety.

Keywords: *Brassica campestris*, Chinese cabbage, correlation, planting density, protected crop, Transylvanian Tableland

INTRODUCTION

Chinese cabbage (*Brassica campestris* var. *pekinensis*) is a member of the *Brassicaceae* family, which may be called brassicas, crucifers or cole crops. This includes various crops such as broccoli, Brussels sprouts, cauliflower, cabbage, radish and others (Burt *et al.*, 2006). It has a short vegetation period, and it belongs to that group of plants which are the fastest growing of all leafy vegetables, in good conditions heads can be cut ten weeks after sowing; loose-headed types two to three weeks sooner, while seedlings four to five weeks after sowing (Larcom, 2003).

The spring Chinese cabbage culture is one of the most profitable culture, because of its short vegetative period, high yield, and of the high demand for fresh vegetable from this time of the year (Kalisz, 2005). This species is very sensitive to bolting which is caused by low temperature during early growth. Bolting occurs when the flower stalk elongates within the head and is most advanced when the flower stalk breaks through the top of the head.

Yields of up to 100 t/ha are possible, with good commercial yields in the range of 50 to 70 t/ha (Burt *et al.*, 2006; Clarke, 2004), the weight of the cabbage heads can vary between 1.4-4.5 kg (Larcom, 2008).

Highest yield can be obtained when the planting density is higher (Hill, 1991; Krung and Basnayake, 1987). Regarding the plants diameter, these are higher when fertilization is made with higher doses of fertilizers (Hill, 1991).

In their studies Chirasantchai and Sidathani (1994) obtained highest production when the planting density was smaller, so the increasing of plants number on the surface had no effect on the increasing of the yield.

MATERIALS AND METHODS

The research has been carried out in the polyethylene tunnel from Vegetable Growing Department of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, from February to June, in 2011.

The purpose of the experiment was the establishment of that planting density for each used variety which provides the highest yields of Chinese cabbage, in early crops in Transylvanian area.

To achieve the objectives of this experiment a bifactorial experiment was organized, which involved the following factors:

- Factor A: variety:
 - a₁: - ‘Granat’
 - a₂: - ‘Vitimo F1’
- Factor B: planting density:
 - b₁: - 100000 plants/ha
 - b₂: - 80000 plants/ha
 - c₃: - 66667 plants/ha

By these factors combination six experimental variants were obtained, which are presented in Tab. 1.

Tab. 1

Experimental variants

Nr. of variant	Variety	Planting distance
1.	‘Granat’	100000
2.	‘Granat’	80000
3.	‘Granat’	66667
4.	‘Vitimo F1’	100000
5.	‘Vitimo F1’	80000
6.	‘Vitimo F1’	66667

Each experimental variant was placed into three repetitions, the surface of an experimental plot being 3 m².

The sowing was made in 25th of February, the seeds being sown one by one in small nutrient pots. After a few weeks, when the seedlings had 3-4 true leaves, there were transplanted in bigger pots.

The establishment of the experimental crop was effectuated in 30th of March, using the following distances: between rows 0.50 m, while between plants on rows the distance ranged between 0.20-0.30 m, according to the used density.

During the vegetative period general and special maintenance of the culture was realized, taking care of a proper irrigation and ventilation, well being known that the lack of water and very high temperatures are playing a high part in the bolting of this species.

At planting, at one month after this and at harvest observations were made regarding plants growth and development.

RESULTS AND DISCUSSIONS

At ‘Granat’ variety, which was planted at the density of 80000 plants/ha were measured the highest average plants height (60.17 cm) and diameter (68.33 cm), but the

smaller number of leaves (in average only 26.83 leaves on every plant). Plants with highest weight (1.34 kg) and in the same time the highest number of leaves (in average 56.00) were obtained at ‘Vitimo’ hybrid, planted at the same density (Tab. 2).

Tab. 2

Development degree of plants before harvest

Variant			Plant			
No.	Variety / Hybrid	Density (plants/ha)	Height (cm)	Diameter (cm)	Weight (g)	Number of leaves
1	‘Granat’	100000	55.83	61.17	1.04	26.83
2	‘Granat’	80000	60.17	68.33	1.21	26.83
3	‘Granat’	66667	52.83	61.00	1.08	27.50
4	‘Vitimo F1’	100000	28.83	52.83	1.23	52.83
5	‘Vitimo F1’	80000	30.17	53.50	1.34	56.00
6	‘Vitimo F1’	66667	28.17	53.33	1.32	50.50
Average			42.67	58.36	1.20	40.08

Between total weight and total leaf number there exists a significant positive relationship (the correlation coefficient, with a value of 0.85 being higher than the value of $p_{(5\%)}=0.81$, for the six experimental variants), which means that with the increasing of the leaf numbers the plant the weight is increasing to (Fig. 1).

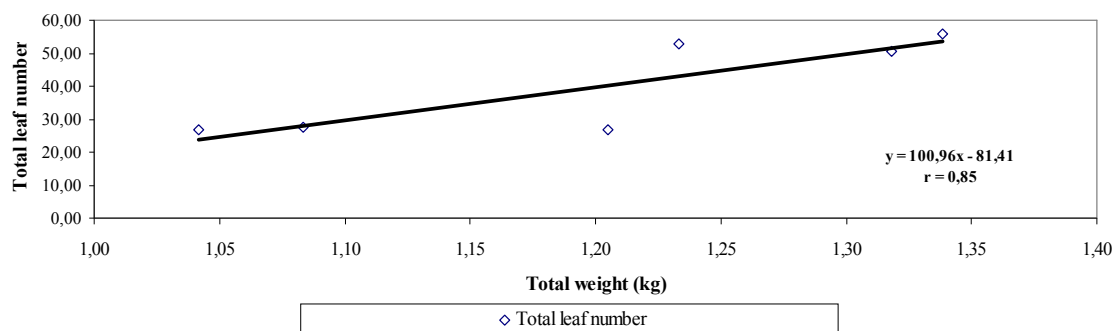


Fig. 1. Relationship between total number of leaves and total weight (n=6, $p_{(5\%)}=0.81$, $p_{(5\%)}=0.92$)

Regarding the development degree of the cabbage heads after harvest it can be observed that as in case of the entire plots, the highest average height (58.00 cm) and head diameter (57.67 cm) was observed at ‘Granat’ variety, at the density of 80 thousand plants/ha, but it is worth nothing that at this variety was registered the highest average head weight (1.07 kg), which means that the losses of production, not only at this variant, but in general at ‘Granat’ variety, are smaller than at ‘Vitimo’ hybrid (Tab. 3). While the difference between total plants and heads weight varied between 80-110 g at ‘Granat’ variety at ‘Vitimo’ hybrid the difference varied between 310-360 g (Fig. 2). Regarding the number of leaves from the cabbage heads, those from first variant (‘Granat’ variety planted at 100 thousand plants/ha) formed in average only 21 leaves, while those from ‘Vitimo’ hybrid, from 80 thousand plants/ha had more than 45 leaves.

Tab. 3

Development degree of cabbage head at harvest

Variant			Cabbage head			
No.	Variety / Hybrid	Density (plants/ha)	Height (cm)	Diameter (cm)	Weight (g)	Number of leaves
1	'Granat'	100000	57.50	48.50	0.97	21.00
2		80000	58.00	57.67	1.07	21.17
3		66667	52.83	57.00	0.98	21.67
4	'Vitimo F1'	100000	29.33	29.17	0.91	42.83
5		80000	30.67	21.83	0.98	45.50
6		66667	29.17	26.00	0.97	40.17
Average			42.92	40.03	0.98	32.06

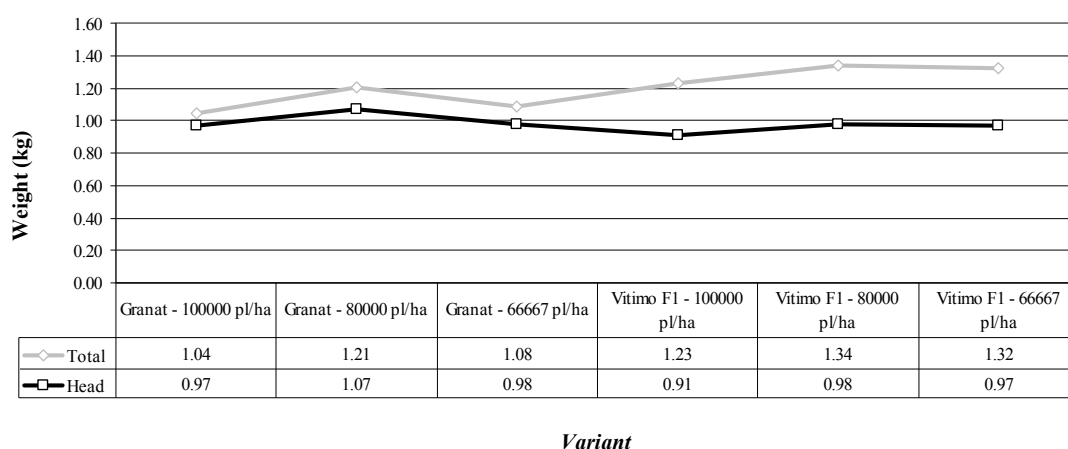


Fig. 2. Comparison between total plant and head weight

In the graphical representation of the relationship of some studied factors can be observed, that even if the correlation coefficients are smaller than $p(5\%)=0.81$, there exists a positive relationship between the weight and height, and between weight and diameter, but a negative one between the weight and number of leaves (Fig. 3).

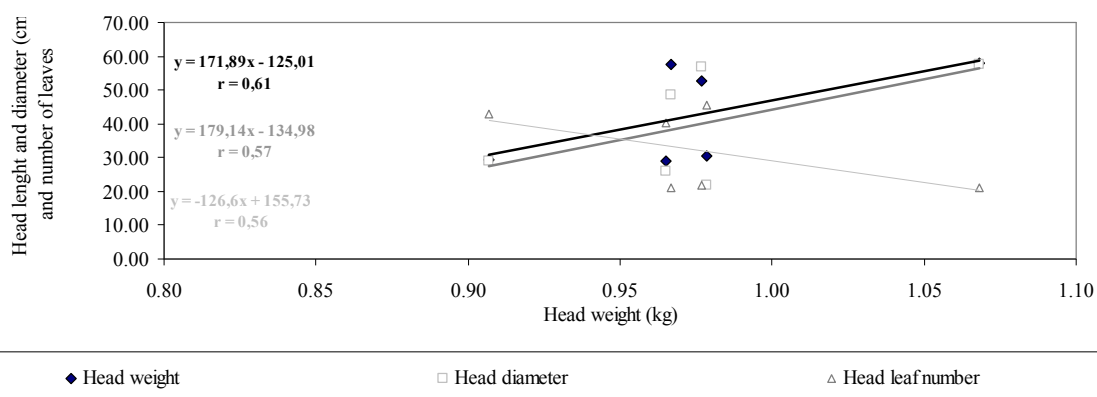


Fig. 3. Relationship between head weight and height, diameter and total leaf number from cabbage head ($n=6$, $p(5\%)=0.81$, $p(5\%)=0.92$)

As visible in the Fig. 4 'Vitimo' hybrid had more leaves, so while 'Granat' variety had in average 5-6 leaves in the rosette and 21-22 in the cabbage heads, plants from 'Vitimo' had

almost twice as much, in average 10-11 leaves in the rosette and between 40 and 46 in the heads. This can be explained by the fact that ‘Vitimo’ hybrid forms a compact head, and its vegetative period is longer than that of ‘Granat’ variety.

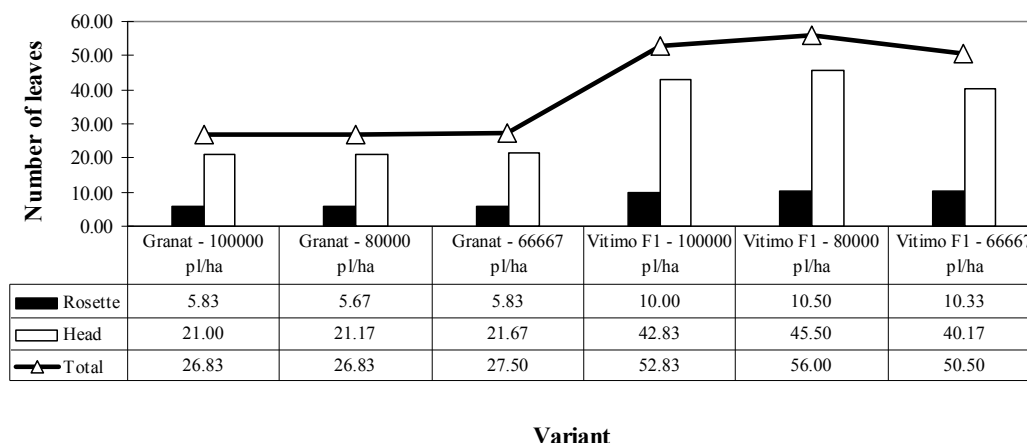


Fig. 4. Leaf layout on plants

At ‘Granat’ variety the plants average height has increased from planting to harvest continuously (with 19.00-23.67 cm in the first month and with 13.83-23.50 cm until harvest), while at ‘Vitimo’ was observed the increase of this factor in first month (with 24.50-29.17 cm), after which the height has decreased (with 6.67-12.00 cm), because the leaves overlapped to form the more compact cabbage head (Fig. 5).

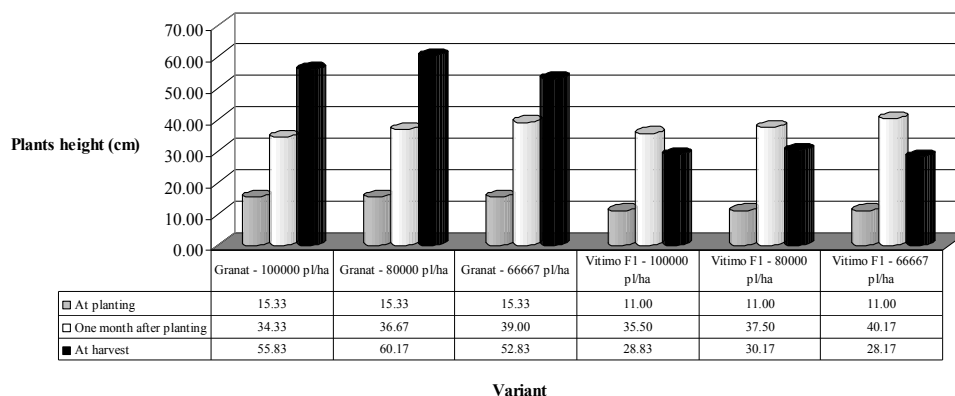


Fig. 5. Plants height evolution from planting to harvest

Plant diameter evolution from planting to harvest was similar at both cultivars, so the diameter increased continuously through the vegetative period. The highest increasing in the first month (32.67 cm) was observed at ‘Granat’ variety, planted at a density of 66.7 thousand plants/ha, while the lowest one (19.67 cm) at the same variety, but at the density of 100 thousand plants/ha. Until harvest the plants diameter from ‘Vitimo’ hybrid, planted at the lowest density grew with only 10.17 cm, while those from ‘Granat’ variety, planted at 80 thousand plants/ha with 27.50 cm (Fig. 6).

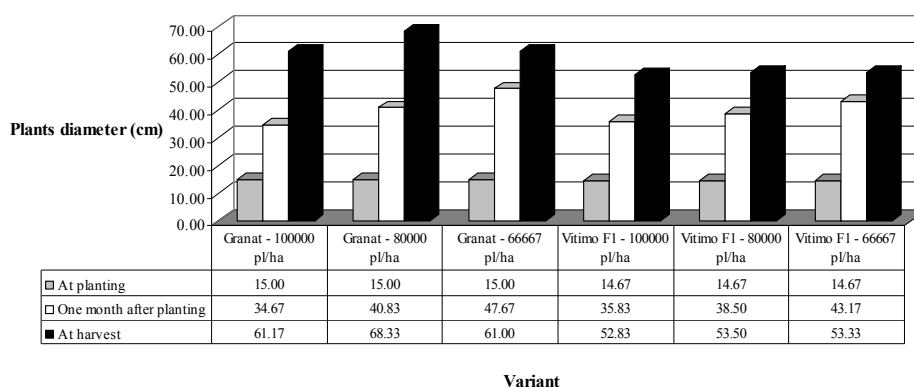


Fig. 6. Plants diameter evolution from planting to harvest

As seen in the beginning of this paper, ‘Vitimo’ hybrid has more leaves than ‘Granat’ variety, this can be seen in the next figure too. In one month at ‘Granat’ variety the number of leaves has increased between 10-11 leaves, while until harvest the plants formed another 9-10 leaves. At ‘Vitimo’ hybrid the increase of this factor was similar but only in the first analyzed period, because until harvest occurred the plants formed another 33-38 leaves (Fig. 7).

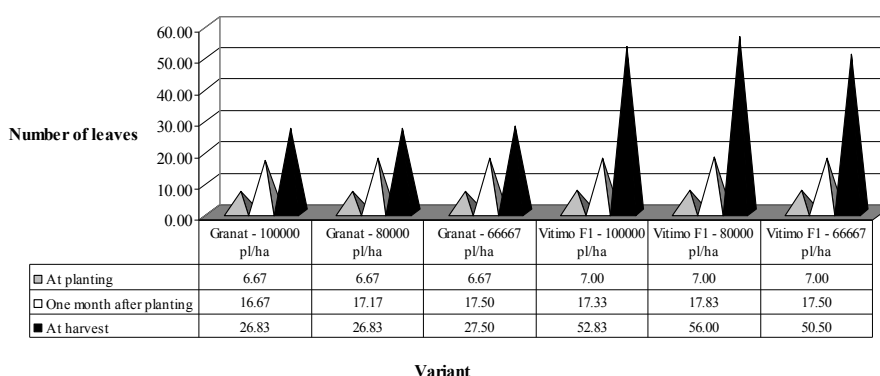


Fig. 7. Leaf number evolution from planting to harvest

The results regarding the bolting of plants showed that this physiological disorder can cause high losses in the total yield. In Fig. 8 can be seen that a large percent of plants bolted at ‘Granat’ variety, while at ‘Vitimo’ there were no bolted plants through the growing season.

At one month after planting, the highest bolting percentage (16.67%) was recorded at the density of 80 thousand plants/ha, while at harvest the highest bolting percentage (35.00%) was recorded at the density of 66.67 thousand plants/ha.

The average bolting percentage was 5.28%, at one month after planting, and 10.83% at harvest.

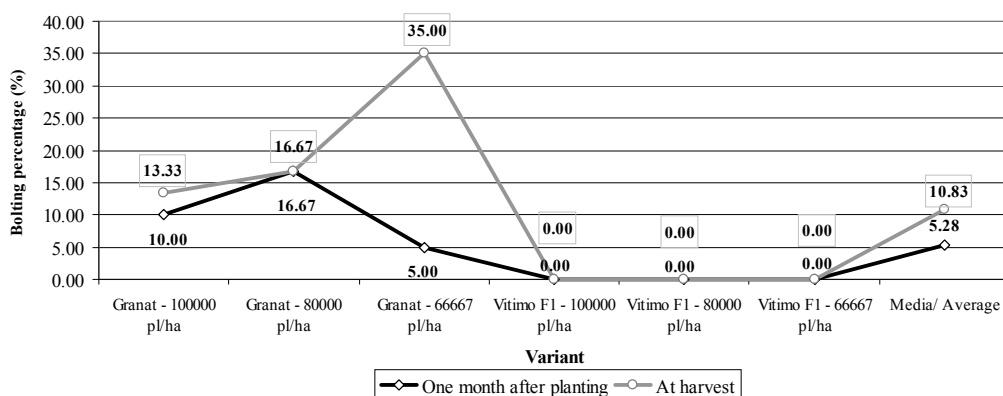


Fig. 8. Bolting percentage

Analyzing the unilateral influence of the cultivar upon the yield (Tab. 4) can be observed that the highest yield was obtained when ‘Granat’ variety was used. Hybrid ‘Vitimo’ realized only 77.76 t/ha, which was lower with 11.02% than the yield recorded at the other cultivar (the control variant), the difference being significant negative.

Tab. 4

Unilateral influence of cultivar upon the Chinese cabbage yield

Cluj-Napoca, 2011

Variant	Average yield (t/ha)	Relative yield (%)	Difference (t/ha)	Significance	Relative yield (%)	Difference (t/ha)	Significance
‘Granat’	86.42	100.0	0.00	Ct.	105.3	4.33	-
‘Vitimo F1’	77.76	89.98	-8.66	o	94.7	-4.33	-
Average	82.09	-	-	-	100.0	0.00	Ct.

LSD (p 5%)

6.84

LSD (p 1%)

15.80

LSD (p 0.1%)

50.29

Tab. 5

Unilateral influence of planting density upon the Chinese cabbage yield

Cluj-Napoca, 2011

Variant	Average yield (t/ha)	Relative yield (%)	Difference (t/ha)	Significance	Relative yield (%)	Difference (t/ha)	Significance
Planting density (plants/ha)							
66667	64.72	100.0	0.00	Ct.	78.8	-17.36	ooo
80000	87.87	135.80	23.15	***	107.0	5.78	*
100000	93.67	144.73	28.95	***	114.1	11.58	***
Average	82.09	-	-	-	100.0	0.00	Ct.

LSD (p 5%)

5.12

LSD (p 1%)

7.45

LSD (p 0.1%)

11.18

The yields observed in case of the unilateral influence of planting densities upon the yield (Tab. 5) varied between 64.72 and 93.67 t/ha. The lowest yield was registered at the lowest planting density (66.67 thousand plants/ha). Compared to this yield the yields obtained

at the other planting densities were higher with 35.8%, at 80 thousand plants/ha, respectively with 44.73% at 100 thousand plants/ha, both differences being very significant positives.

Compared to the average yield (82.09 t/ha), the yield obtained at 66.67 thousand plants/ha registered a very significant negative difference, while that obtained at 100 thousand plants/ha a very significant positive one.

Regarding the combined influence of the cultivar and planting density upon the yield, in Tab. 6 it can be seen that the yields registered at ‘Granat’ variety ranged between 65.11 and 97.47 t/ha. The lowest yield was obtained at the density of 66.67 plants/ha. Taking this variant as control one, the yields obtained at the other densities, 94.47 (at 80 thousand plants/ha) and 96.67 (at 100 thousand plants/ha) registered differences that are very significant positive from statistically point of view.

If the average yield of this variety is taken as control variant, the yield obtained at the density of 66.67 thousand plants/ha is lower with 24.7% and the difference between them is very significant negative.

Similar to ‘Granat’ variety, lowest production (64.33 t/ha) at ‘Vitimo’ hybrid was recorded at the lowest planting density. A distinct significant difference was observed at the density of 80 thousand plants/ha (the difference being 13.94 t/ha), and a very significant difference at the density of 100 thousand plants/ha (the difference being 26.34 t/ha).

Compared to the average yield of this hybrid (77.76 t/ha) was noticed a distinct significant negative difference at the density of 66.67 t/ha, where the production was lower with 17.3%, and a distinct significant positive one, at the density of 100 thousand plants/ha, where the yield was higher with 12.91 t/ha.

Tab. 6
Combined influence of planting density and cultivar upon the Chinese cabbage yield
Cluj-Napoca, 2011

Variant		Average yield (t/ha)	Relative yield (%)	Difference (t/ha)	Significance	Relative yield (%)	Difference (t/ha)	Significance
Planting density (plants/ha)	Cultivar							
66667	‘Granat’	65.11	100.0	0.00	Ct.	75.3	-21.30	ooo
80000	‘Granat’	97.47	149.70	32.36	***	112.3	11.05	**
100000	‘Granat’	96.67	148.47	31.56	***	111.9	10.25	*
Average		86.42	-	-	-	100.0	0.00	Ct.
66667	‘Vitimo F1’	64.33	100.0	0.00	Ct.	82.7	-13.42	oo
80000	‘Vitimo F1’	78.27	121.67	13.94	**	100.7	0.51	-
100000	‘Vitimo F1’	90.67	140.95	26.34	***	116.6	12.91	**
Average		77.76	-	-	-	100.0	0.00	Ct.
LSD (p 5%)					7.25			
LSD (p 1%)					10.54			
LSD (p 0.1%)					15.81			

CONCLUSIONS

Even if a higher number of leaves were formed by ‘Vitimo’ hybrid, all the other measured characteristics had higher values at ‘Granat’ variety.

Plants height had a continuous evolution only at ‘Granat’ variety, while at ‘Vitimo’ hybrid the average height decreased after a period, forming in this way the more compact cabbage heads.

Meanwhile at ‘Vitimo’ hybrid no plant emitted flower stalks, at ‘Granat’ variety the bolting percentage reached even a value higher than 35%.

Taking into account only the unilateral influence of the studied factors, high yield can be obtained using 'Granat' variety and a density of 100 thousand plants/ha, while the variant with the higher yield was the same cultivar, but planted at a density of 80 thousand plants/ha.

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