ACTA Acta Sci. Pol., Hortorum Cultus 8(4) 2009, 79-85

EFFECT OF PLANT DENSITY AND IRRIGATION UPON YIELD AND SELECTED TECHNOLOGICAL FEATURES OF SOME CELERIAC (*Apium graveolens* L. var. *rapaceum*) CULTIVARS

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Abstract. During the studies conducted in the years 2004–2005, in the Experimental Farm „Felin" of the University of Life Sciences in Lublin we assessed the effect of irrigation and plant density upon the yield and selected technological features (mean weight of root and the occurrence of empty spaces) in a few currently grown celeriac cultivars. A significant influence of the examined factors upon the quantity and quality of celeriac yield was demonstrated. On average, for the study years, the yield of non-watered plants ranged from 34.7 to 48.8 t ha^{-1} and the yield of watered plants – from 47.1 to 66.3 t ha^{-1}. The increased plant density from 37.0 thousand pcs. to 55.6 thousand pcs. ha^{-1} enabled us to obtain greater yield of non-watered plants by 15.6%, and of watered plants – by 21.5%. The examined factors affected the mean weight of root in the assessed celeriac cultivar, the sizes of empty spaces occurring in them, as well as the participation of roots with empty spaces in the marketable yield.

Key words: empty spaces, root weight, celeriac cultivars, technological features

INTRODUCTION

The celeriac roots constitute a valuable raw material for processing industry. As a raw material, roots can be frozen, canned, dried and used for producing juices. The technological value of celeriac roots designed for freezing and canning is significantly decreased when empty spaces occur in them. The hitherto conducted studies reveal that the formation of empty spaces in the celeriac thickenings stimulates all the factors that influence the increase of their weight [Krug 1991], such as: fertilization [Osińska et al. 1982, Michalik et al. 1994], irrigation [Jabłońska-Ceglarek et al. 1982, Knaflewski 1982], increased spacing of plants and the type of soil [Kamionka 1982]. The aptness to forming empty spaces is also a cultivar feature [Jabłońska-Ceglarek et al. 1982,

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Kamionka 1982, Knaflewski 1982, Michalik et al. 1994]. In the studies conducted by Kamionka [1982] empty spaces enlarged with the delaying of plant harvesting term. Similarly, in the studies conducted by Umięcka and Michalik [1988], the participation of thickenings with empty spaces increased with the prolongation of plant vegetation period.

The aim of the conducted studies was to assess the effect of plant irrigation and density upon yield and selected technological features (mean weight of roots and the occurrence of empty spaces) in some of currently grown cultivars of celeriac.

MATERIAL AND METHODS

The studies were conducted in the years 2004–2005, in the Experimental Farm Felin, University of Life Sciences, Lublin. The experimental material consisted of 5 cultivars of celeriac, recommended for processing industry: Mentor, President, Luna F_1, Briliant, Diamant. The plants were grown from potted seeding, manufactured in a glasshouse. The celeriac seeds were sown in mid March, after the seedlings formed 2 proper leaves they were thinned into multi-pots, and they were planted in the field on the 15th day of May 2004 and on the 12th day of May 2005. Two spacings of seedlings planting were applied: 45×40 cm (density 55.6 thousand pieces ha^{-1}) and 67.5×40 cm (density 37.0 thousand pieces ha^{-1}). The experiment was established in the split-plot system in four repetitions. The plot surface equaled 10.72 m^2. Before seedlings planting fertilization was applied in the following amounts: 130 kg N · ha^{-1}, 150 kg P_2O_5 · ha^{-1} and

Table 1. Decade and monthly precipitation totals in celeriac vegetation periods in the years 2004–2005 (multi-annual averages 1951–1995)

Tabela 1. Dekadowe i miesięczne sumy opadów w okresie wegetacji selera korzeniowego w latach 2004–2005 (średnie wieloletnie 1951–1995)

	Month Miesiąc	Decade totals – Średnia dekadowa			Monthly totals Suma miesięczna mm	Multi-annual monthly totals Miesięczna średnia wieloletnia mm
		I	II	III		
2004	V	10.1	11.3	16.6	38.0	57.2
	VI	3.7	25.9	20.3	49.9	65.9
	VII	4.7	27.5	58.3	90.5	73.6
	VIII	14.7	9.1	24.7	48.5	71.1
	IX	1.2	0.4	12.6	14.2	51.4
	X	7.4	11.3	0.4	19.1	40.5
	Total – Razem				259.3	359.7
2005	V	32.8	65.0	0.2	98.0	57.2
	VI	47.1	7.4	1.4	55.9	65.9
	VII	0.0	22.4	87.4	109.8	73.6
	VIII	103.9	3.2	1.6	108.7	71.1
	IX	0.0	8.9	9.1	18.0	51.4
	X	0.4	2.7	5.5	8.6	40.5
	Total – Razem				399.0	359.7

220 kg $K_2O \cdot ha^{-1}$ in the forms of ammonium nitrate, triple superphosohate and potassium sulphate. The plant protection was conducted in accordance with the principles applicable to this vegetable.

Plant irrigation was conducted by means of dropping lines. Additional irrigation was conducted 9 times in 2004, and 12 times in 2005. Irrigation was started at soil water potential of -40 kPa. Once, in the initial period of plant growth, i.e. in May and June water dose was applied that corresponded to 15–20 mm of precipitation, later – 25 mm.

Roots harvesting was conducted on the 25th day of October. The marketable yield of roots was defined after the leaves and lateral roots had been cut. In 20 roots from each repetition widths and heights of empty spaces were measured. The obtained results were statistically elaborated by means of variance analysis method for k-ply classification. The statistical conclusion was performed on the basis of T. Tukey's multiple confidence intervals with the significance level $\alpha = 0.05$. The means marked with the same letter do not significantly differ among themselves.

The meteorological data concerning celeriac vegetation period are presented in table 1.

RESULTS AND DISCUSSION

The conducted studies demonstrated a significant influence of the applied plant density and irrigation upon the yield of the examined cultivars of root celery (tab. 2). On average, for the study years, the yield of non-irrigated plants was within the range from 34.7 to 48.7 $t \cdot ha^{-1}$ and was significantly smaller from that collected from the irrigated plots, where it ranged from 47.1 to 66.3 $t \cdot ha^{-1}$. According to Kaniszewski [2005], celeriac plants in vegetation period need about 400–500 mm of precipitation. In the study years the precipitation total in plant vegetation period was smaller than that value (tab. 1), so irrigation was necessary. In the year 2004 the total precipitation from May to end of October was 259.3 mm and was smaller by 100,4 mm from multi-annual mean for this period. The greatest precipitation insufficiency was reported in September and October – the precipitations constituted, respectively 27.6 % and 47.2% of the multi-annual total for these months. In the year 2005 the precipitation total equaled 399.0 and was greater by 39.4 mm from the multi-annual mean. However, the uneven precipitation distribution was the reason for more frequent additional irrigation in the year 2005 than in 2004. In the year 2005 precipitation insufficiency was observed from as early as the second decade of August until as late as the end of September (the precipitation total in the second and third decade of August was merely 4.8 mm, in September – 18 mm, and in October – 8.6 mm).

On average, for the study years, irrigation increased the yield of plants grown in the density of 37 thousand pieces $\cdot ha^{-1}$ by 37.8%, and of those grown in the density of 55.6 thousand pieces ha^{-1} by 44.9% (tab. 2).

The increased density of non-irrigated plants from 37 thousand pieces to 55.6 thousand pieces $\cdot ha^{-1}$ enabled us to obtain the yield greater by 15.6%, and as a result of analogous density of irrigated plants the yield greater by 21.5% was obtained.

From among non-irrigated plants, grown in the density of 37 thousand pieces $\cdot ha^{-1}$ Luna F_1 turned out to be the most fertile cultivar. The plants of Briliant and Diamant cultivars responded best to irrigation. After the density had been increased to 55.6 thousand pieces, the highest root yield was obtained in the Briliant cultivar, and with the cooperation of two factors under discussion, i.e. density and irrigation – in the Mentor cultivar.

Table 2. The effect of plant density and irrigation upon yield of 5 celeriac cultivars, t · ha^{-1}
Tabela 2. Wpływ zagęszczenia roślin i nawadniania na plonowanie 5 odmian selera korzeniowego, t · ha^{-1}

Cultivar Odmiana	Density pcs. · ha^{-1} Zagęszczenie szt. · ha^{-1}	2004		2005		Mean for years Średnio dla lat	
		NI	I	NI	I	NI	I
Mentor	37.0 thousand tysięcy	35.2 a	48.9 cde	34.1 a	50.7 cde	34.7 a	49.8 ef
President		36.6 ab	56.6 f	38.9 ab	47.4 cde	37.8 ab	52.0 ef
Luna F_1		43.7 bc	44.8 cd	37.4 ab	49.3 cde	40.6 bc	47.1 de
Brillant		37.7 ab	55.9 fg	39.6 ab	57.0 fg	38.7 ab	56.5 fg
Diamant		39.2 ab	54.1 ef	35.2 a	56.3 fg	37.2 ab	55.2 f
Mean – Średnio		38.5 A	52.1 C	37.0 A	52.1 C	37.8 A	52.1 C
Mentor	55.6 thousand tysięcy	49.5 cd	70.1 h	46.2 cd	55.0 fg	47.9 de	62.6 gh
President		45.0 cd	73.4 h	38.4 a	54.5 fg	41.7 cd	64.0 h
Luna F_1		40.0 ab	62.9 g	37.3 a	56.7 fg	38.7 ab	59.8 g
Brillant		52.4 d	73.0 h	41.1 a	59.5 fg	48.8 cd	66.3 h
Diamant		51.0 cd	77.3 h	36.1 ab	50.6 cde	43.6 cd	64.0 h
Mean – Średnio		47.6 B	71.3 D	39.8 A	55.3 C	43.7 B	63.3 D

NI – non-irrigated plants – rośliny nienawadniane, I – irrigated plants – rośliny nawadniane
*means marked with the same letters do not significantly differ between each other – średnie oznaczone tą samą literą nie różnią się istotnie

Table 3. The effect of plant density and irrigation upon the mean root weight in 5 celeriac cultivars, kg
Tabela 3. Wpływ zagęszczenia roślin i nawadniania na średnią masę zgrubień 5 odmian selera korzeniowego, kg

Cultivar Odmiana	Density pcs. · ha^{-1} Zagęszczenie szt. · ha^{-1}	2004		2005		Mean for years Średnio dla lat	
		NI	I	NI	I	NI	I
Mentor	37.0 thousand tysięcy	0.95 cd	1.32 ijkl	0.92 cd	1.37 jkłł	0.94 cd	1.35 jk
President		0.99 cde	1.53 ł	1.05 def	1.28 hlij	1.02 def	1.41 kl
Luna F_1		1.18 fghi	1.21 ghij	1.01 cdef	1.33 ijkl	1.10 efgh	1.27 ij
Brillant		1.02 cdef	1.51 lł	1.07 defg	1.54 ł	1.05 defg	1.50 l
Diamant		1.06 defg	1.46 klł	0.95 cd	1.52 ł	1.01 def	1.49 l
Mean – Średnio		1.04 C	1.41 E	1.00 C	1.41 E	1.02 B	1.41 D
Mentor	55.6 thousand tysięcy	0.89 bcd	1.26 hij	0.83 abc	0.99 cde	0.86 bc	1.13 fgh
President		0.81 abc	1.32 ijkl	0.69 a	0.98 cde	0.75 a	1.15 ghi
Luna F_1		0.72 ab	1.13 efgh	0.67 a	1.02 cdef	0.70 a	1.08 efgh
Brillant		0.94 cd	1.31 ijkl	0.74 ab	1.07 defg	0.84 bc	1.19 hi
Diamant		0.92 cd	1.39 jklł	0.65 a	0.91 cd	0.79 ac	1.15 ghi
Mean – Średnio		0.86 B	1.28D	0.72 A	0.99 C	0.79 A	1.14 C

NI – non-irrigated plants – rośliny nienawadniane, I – irrigated plants – rośliny nawadniane
*means marked with the same letters do not significantly differ between each other – średnie oznaczone tą samą literą nie różnią się istotnie

The examined factors also significantly affected the mean weight of roots in the assessed celeriac cultivars (tab. 3). The mean root weight in non-irrigated plants, grown in the density of 37 thousand pieces was 1.02 kg, and in irrigated plants it amounted to 1.41 kg. The density of cultivated plants to 55.6 thousand pieces in the case of non-irrigated plants caused the decrease of mean root weight by 21.6%, and in the case of irrigated plants – by 19.1%.

Irrespectively of the experiment factors, we found a distinct cultivar tendency to form empty spaces. The least roots with empty spaces were observed in the Luna F_1

Table 4. Effect on plant density and irrigation upon the participation of roots with empty spaces, %
Tabela 4. Wpływ zagęszczenia roślin i nawadniania na udział zgrubień z pustymi przestrzeniami, %

Cultivar Odmiana	Density pcs. · ha^{-1} Zagęszczenie szt. · ha^{-1}	2004		2005		Mean for years Średnio dla lat	
		NI	I	NI	I	NI	I
Mentor	37.0 thousand tysięcy	100.0	100.0	93.0	100.0	96.5	100.0
President		100.0	100.0	96.0	100.0	98.0	100.0
Luna F_1		47.0	62.0	34.0	42.0	40.5	52.0
Briliant		100.0	97.0	98.0	100.0	99.0	98.5
Diamant		81.0	89.0	59.0	67.0	70.0	78.0
Mean – Średnio		85.6	89.6	76.0	81.8	80.8	85.7
Mentor	55.6 thousand tysięcy	100.0	100.0	87.0	100.0	93.5	100.0
President		100.0	98.0	81.0	83.0	90.5	90.5
Luna F_1		33.0	37.0	42.0	50.0	41.5	43.5
Briliant		86.0	100.0	91.0	100.0	88.5	100.0
Diamant		71.0	75.0	39.0	68.0	55.0	71.5
Mean – Średnio		78.0	82.0	68.0	80.2	73.8	81.1

NI – non-irrigated plants – rośliny nienawadniane, I – irrigated plants – rośliny nawadniane

Table 5. Effect of plant density and irrigation upon the size (width and height) of empty spaces, cm
Tabela 5. Wpływ zagęszczenia roślin i nawadniania na wielkość (szerokość i wysokość) pustych przestrzeni, cm

Cultivar Odmiana	Density pcs. · ha^{-1} Zagęszczenie szt. · ha^{-1}	2004				2005				Mean for years Średnio dla lat			
		NI		I		NI		I		NI		I	
		w.	h.	w.	h.	w.	h.	w.	h.	w.	h.	w.	h.
Mentor	37 thousand tysięcy	1.8	2.6	2.4	2.6	2.0	2.1	2.7	3.3	1.9	2.4	2.6	3.0
President		1.3	1.5	1.8	2.0	1.2	1.4	1.8	1.7	1.3	1.5	1.8	1.9
Luna F_1		0.8	0.4	1.5	1.4	0.6	0.9	3.0	1.5	0.7	0.7	2.3	1.5
Briliant		1.2	1.5	2.6	2.3	1.3	1.4	1.9	3.1	1.3	1.5	2.3	2.7
Diamant		1.0	1.1	1.2	1.3	1.2	1.1	2.1	1.5	1.1	1.1	1.7	1.4
Mean – Średnio		1.2	1.4	1.9	1.9	1.3	1.4	2.3	2.2	1.3	1.4	2.1	2.1
Mentor	55.6 thousand tysięcy	1.3	1.3	2.3	2.3	1.5	1.1	2.0	3.0	1.4	1.2	2.2	2.7
President		1.2	1.6	1.9	1.9	1.1	1.3	0.9	1.4	1.2	1.5	1.4	1.7
Luna F_1		1.1	0.7	0.7	0.7	0.5	0.9	0.5	1.2	0.8	0.8	0.6	1.0
Briliant		1.2	1.2	1.9	1.7	1.1	1.3	1.2	1.8	1.2	1.3	1.6	1.8
Diamant		1.1	0.7	1.1	1.1	1.1	0.8	1.5	1.6	1.1	0.8	1.8	1.4
Mean – Średnio		1.2	1.1	1.6	1.5	1.1	1.1	1.2	1.8	1.1	1.1	1.4	1.7

NI – non-irrigated plants – rośliny nienawadniane, I – irrigated plants – rośliny nawadniane cultivar (32–62%), and the most – in the Mentor (87–100%), President (81–100%) and Briliant (86–100%) varieties.

Considering the effect of examined factors, it was found that the increased plant density and the related decrease of mean root weight contributed to the decrease of the number of roots with empty spaces (on average from 85.6% to 78% in the year 2004 and from 76.0% to 68.0% in 2005 in non-irrigated plants, and from 89.6% to 82.0% in the year 2004, and from 81.8% to 80.2% in the year 2005 in the case of irrigated plants). The application of irrigation influenced the participation of roots with empty spaces to a small extent, only in the year 2005 in plants growing in larger density increased participation of roots with empty spaces was reported: from 68.0% to 80.2%. Irrigation contributed to significantly increased size of empty spaces (tab. 5) in celeriac roots.

The obtained results are confirmed by literature. The principal influence of a cultivar upon the formation of empty spaces was demonstrated in the works of Kamionka [1982], Knaflewski [1982], as well as of Umięcka and Michalik [1988]. In the studies conducted by Michalik et al. [1994] the participation of roots with empty spaces in the total number of roots, depending on the cultivar, amounted to 44.0–99.2% and in the studies conducted by Umięcka and Michalik [1988] 62,0–99,5%. Gawęda [2005] demonstrated that roots in the Diamant cultivar reveal two times smaller tendency to shriveling up and forming empty spaces, as compared to roots in Briliant cultivar. The conducted studies confirm that the Briliant cultivar reveals a greater tendency to forming empty spaces, but the difference between that cultivar and the Diamant cultivar is not so big. Kamionka [1982] defined the participation of empty spaces in the total surface of celeriac roots cross-section within the range from 0.23–5.10%, and Osińska et al. [1982] found out that the volume of empty spaces in celeriac roots is 3.76–3.80 cm^3. The negative influence of irrigation upon the structure of parenchyma in certain celery cultivars, including the formation of empty spaces, was demonstrated by Knaflewski [1982], and Osińska et al. [1982] did not find such interdependence.

CONCLUSIONS

1. Irrigation and increased celeriac plant density made it possible to obtain greater marketable yield of roots.

2. The tendency to form empty spaces is a distinct cultivar feature, modified by agrotechnical factors. The smallest tendency to form empty spaces was demonstrated by roots in the Luna F_1 cultivar, and the greatest – in the Mentor, President and Brillant cultivars.

3. Irrigation celeriac contributed to the increase of roots weight and the sizes of empty spaces in them.

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WPŁYW ZAGĘSZCZENIA ROŚLIN I NAWADNIANIA NA PLONOWANIE I WYBRANE CECHY TECHNOLOGICZNE KILKU ODMIAN SELERA KORZENIOWEGO (*Apium graveolens* L. var. *rapaceum*)

Streszczenie. Podczas badań przeprowadzonych w latach 2004–2005, w Zakładzie Doświadczalnym Felin UP w Lublinie oceniono wpływ nawadniania i zagęszczenia roślin na plonowanie i wybrane cechy technologiczne (średnia masa zgrubień i występowanie pustych przestrzeni) kilku obecnie uprawianych odmian selera korzeniowego. Wykazano istotny wpływ badanych czynników na wielkość i jakość plonu selera korzeniowego. Średnio dla lat badań, plon roślin nienawadnianych kształtował się w granicach 34,7–48,8 t · ha^{-1}, a roślin nawadnianych 47,1–66,3 t · ha^{-1}. Zwiększenie zagęszczenia roślin z 37 tys. szt. do 55,6 tys. szt. ha^{-1} umożliwiło uzyskanie większego plonu roślin nienawadnianych o 15,6%, a roślin nawadnianych o 21,5%. Badane czynniki wpłynęły istotnie na średnią masę zgrubień ocenianych odmian selera korzeniowego, wielkość występujących w nich pustych przestrzeni oraz udział zgrubień z pustymi przestrzeniami w plonie przemysłowym.

Słowa kluczowe: puste przestrzenie, masa zgrubień, odmiany selera korzeniowego, cechy technologiczne

Accepted for print – Zaakceptowano do druku: 21.12.2009