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FACTORS MODIFYING YIELD QUANTITY AND QUALITY, AS WELL AS THE CHEMICAL COMPOSITION OF THE LEAVES OF LEAF CELERY *Apium graveolens* L. var. *secalinum* Alef. GROWN FROM SEEDLINGS

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Abstract. The usable part of leaf celery consists of the intensely green leaves with strong aroma, used for seasoning when fresh, dried, or frozen. The plants form from several tens to one hundred leaves, which can be cut several times during vegetation. The studies conducted in the years 2006–2008 were aimed at assessing the response of leaf celery to additional irrigation in the periods of humidity deficiency in the soil. The celery seedlings production was started at the beginning of March, the plants were put into the field in the third decade of May, in the spacing of 25 × 25 cm. Leaves were collected twice: in mid August and mid October. A significant effect of watering upon the height of plants was demonstrated, as well as upon the total celery yield quantity, nitrate (V) and total chlorophyll contents. Irrigation contributed to the increase of petiole weight share and decrease of leaf blade share in the weight of whole leaves. No effect of irrigation was found upon the number of leaves, total sugar content in leaf blades, as well as upon the content of essential oil in the whole leaves. A factor that significantly modified the leaf composition was harvest term. It significantly influenced the total sugar content, as well as the contents of nitrates (V) and essential oils in celery leaves. During the first harvest, conducted in mid August, the leaves contained less total sugars, whereas there were more nitrates (V) and essential oil.

Key words: cutting celery, smallage, leaf celery, yield, irrigation, chemical composition, essential oil

INTRODUCTION

Leaf celery *Apium graveolens* L. *var. secalinum* Alef. is a valuable leaf vegetable with seasoning, dietary and curative properties [Atta and Alkofahi 1998, Bonjar 2004,

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Jabłońska-Ryś and Zalewska-Korona 2006, Jabłońska-Ryś 2007, Momin and Nair 2002]. The medicinal properties of celery *Apium graveolens* are used in the diseases of alimentary system, liver, kidneys and rheumatic ailments. The application of celery in folk medicine is well known as well [Saleh et al. 1985, Atta and Alkofahi 1998]. Celery demonstrates its curative properties in skin diseases, as well as diuretic and anti-inflammatory activity. It stimulates metabolism and contains components with anti-oxidation properties [Atta and Alkofahi 1998, Momin and Nair 2002, Yildiz et al. 2008]. The components of *Apium graveolens* reveal anti-bacterial [Bonjar 2004], as well as anti-mycotic activity [Afec et al. 1995]. Celery is a rich source of iron, mineral components and vitamin C. All parts of the plant contain the essential oil: there is 0.09–0.43% in dry herb [Rożek 2007a] and in fruit: 2–3% [Wolski et al. 2001, Sowbhagya et al. 2007]. The main components of celery oil are: limonene, selinene, α pinene, β pinene and myrcene [Saleh et al. 1985, Papamichail et al. 2000, Rożek 2007a, Sowbhagya et al. 2007]. Jałoszyński et al. [2008] emphasize that seasoning plants, such as celery are not only a taste-enhancing additive to dishes, but they also increase their nutritional value and prolong their storage life, because they contain food preserving components. The repellent properties of celery are used in ecological cultivations, where, grown coordinately with cabbage plants, it repels their pests.

Leaf celery *Apium graveolens* L. var. *secalinum* is less popular in cultivation compared with root celery *Apium graveolens* L. var. *rapaceum* and celery *Apium graveolens* L. var. *dulce*. In its look it resembles wild celery the most, and compared to celery *Apium graveolens* L. var. *dulce* it has more leaves and thinner petioles [Rożek 2007b]. Currently the leaves of celery and root celery are more frequently used as raw material for drying [Jałoszyński et al. 2008, Polak 2008], but leaf celery *Apium graveolens* L. var. *secalinum* has much better technological and agrotechnical features. Such features as the intensely green colour of leaves, strong aroma, thin petioles, possibility of several harvests during vegetation and fast growing back of leaves after cutting, as well as better immunity to diseases make this vegetable, besides its seasoning and decorative function when it is fresh, a very good raw material for freezing and drying.

In this paper it was demonstrated to what extent irrigation and leaf harvest term affect the biometric features, yield and chemical composition of the leaf celery leaves.

MATERIAL AND METHODS

The studies were conducted in the years 2006–2008 in the Experimental Farm Felin of the University of Life Sciences in Lublin. The object of studies was leaf celery *Apium graveolens* L. var. *secalinum*, cultivar: Safir. Seedlings were produced in a glasshouse. Seeds for the seedlings were sown on the 4th–5th March. After the first proper leaves appeared, the seedlings were thinned into the seedling palettes. Before planting the seedlings fertilization was applied in the following amounts: N – 100 kg·ha^{-1}, P_2O_5 – 120 kg·ha^{-1}, K_2O – 150 kg·ha^{-1}. After the first leaf harvest 50 kg N·ha^{-1} was applied in the form of calcium nitrate. The seedlings in the phase of 5–7 leaves was planted in the field annually in the third decade of May, in the spacing: 25 × 25 cm, on plots of the surface of 2.5 m^2. The experiment was established using the method of random blocks in 4 repetitions. During vegetation chemical protection was conducted with the use of Amistar 250 SC and Bravo 500 SC preparations against celery septoriosis.

In the periods of humidity deficiency in the soil plant watering was conducted with the use of dripping lines. The dose corresponding to 25 mm of precipitation was applied six times (12.06, 19.06, 3.07, 24.07, 13.09, 21.09) in the year 2006, four times (24.07, 21.08, 25.09, 3.10) in the year 2007 and eight times (22.05, 30.05, 9.06, 17.06, 24.06, 1.08, 11.08, 25.08) in the year 2008. Leaf harvest and yield quantity evaluation was performed in 2 terms: in mid August and in mid October. The industrial celery yield consisted of healthy leaves, cut 3 cm over the soil surface. Before the harvest measurements were performed on 4 plants, chosen at random from each plot (16 measurements in combination). The assessment concerned plant height, number of leaves, share of leaf blade and petiole weight in the weight of leaves.

In the laboratory tests on fresh material the total chlorophyll content was determined (using Mac Kinney's method), the content of total sugars (with the use of Schoorl-Luff method), dry matter content (using dryer method), as well as the content of nitrates (V) – with the use of reflectometric method. In the whole leaf celery leaves the essential oil content was determined with the use of Deryng's apparatus (Polish Pharmacopoeia VII). The obtained results were statistically worked out with the use of variance analysis method for double classification. The significance of differences was evaluated with Tukey's confidence intervals at the level of significance $\alpha = 0.05$.

RESULTS AND DISCUSSION

Leaf celery may be grown from seeds sown directly into the field [Rożek 2006] or from seedlings [Rożek 2005, Rożek 2007b]. Growing from seed sowing requires smaller expenditures, but it is more fallible, because of long seed germination, problems with appropriate soil humidity and lack of recommendations of how to protect this species from weeds. Celery has high water requirements. During vegetation the plants need 400–500 mm of precipitation [Kaniszewski 2005]. According to Kaniszewski [2006] celeries should be irrigated so as to prevent soil humidity decrease below 75–80% of the field water capacity. High water requirements of root celery (*Apium graveolens* L. var. *rapaceum*) and celery (*Apium graveolens* L. var. *dulce*) were demonstrated in the works by: Osińska et al. [1982], Evers et al. [1997], Rumasz et al. [1999], Elkner and Kaniszewski [2001], Breschini and Hartz [2002], Rożek [2004]. The water needs of leaf celery are similar to those of celery, that is why it also responds well to additional irrigation in the periods of water deficiency [Rożek 2007b]. In the presented paper the total yield of leaf celery was the sum of leaf yield from the first harvest, conducted in mid August and from the second harvest (conducted in mid October). The total leaf yield of the irrigated plants was 83.81 $t \cdot ha^{-1}$ and was higher by 45.9% than the yield of non-irrigated plants (tab. 1). The author's previous studies [Rożek 2007b] revealed that both irrigation and increased plant density contribute to significant increase of the yield. The response to irrigation of the celery grown from seeds sown directly into the field is stronger, and the yield changes in a broader scope, compared to growing from seedlings.

During previously conducted studies the yield of non-irrigated plants grown from seeds was 1.71–3.04 kg · m^{-2}, and in the case of irrigated plants it was 4.34–12.26 t · ha^{-1} [Rożek 2006]. The yield of non- irrigated plants, grown from seedlings, after the application of three leaf harvests was 6.12–7.36 kg · m^{-2}, and in the case of irrigated plants: 9.16–11.97 kg · m^{-2} [Rożek 2007b].

Table 1. The yield of leaf celery Safir cv. (t · ha^{-1}, mean 2006–2008)
Tabela 1. Plon selera listkowego odmiany Safir (t · ha^{-1}, średnio 2006–2008)

Harvest Zbiór	Non-irrigated plants Rośliny nienawadniane	Irrigated plants Rośliny nawadniane	Mean Średnio
I harvest I zbiór	27.76 b	47.61 a	37.68 A
II harvest II zbiór	29.70 b	36.20 c	32.95 A
Mean Średnio	57.46 B	83.81 A	

Means followed by the same letter are not significantly different at α = 0.05
Średnie oznaczone tą samą literą nie różnią się między sobą istotnie przy α = 0,05

Irrigation is a significant factor affecting plant height as well. In the presented studies non- irrigated plants during the first harvest obtained the height of 35.3 cm and formed on average 70.7 leaves (tab. 2, 3), whereas during the second harvest it was 44.2 cm and 102.2 leaves. Irrigated plants were significantly higher, both during the first (49.4 cm), and second harvest (51.9 cm), but they did not significantly differ in the number of leaves they formed from non-irrigated plants (tab. 3).

Table 2. Plant height of leaf celery Safir cv. (cm)
Tabela 2. Wysokość roślin selera listkowego odmiany Safir (cm)

Harvest Zbiór	Non-irrigated plants Rośliny nienawadniane	Irrigated plants Rośliny nawadniane	Mean Średnio
I harvest I zbiór	35.3 c	49.4 ab	42.4 B
II harvest II zbiór	44.2 b	51.9 a	48.1 A
Mean Średnio	39.8 B	50.7 A	

Explanations see table 1 – Oznaczenia jak w tabeli 1

Irrigation significantly influenced the change of leaf element proportion. In the leaves of irrigated plants the share of petioles increased (to 53.9%) and the share of blades decreased (46.1%, tab. 4), which is not an advantageous phenomenon in growing for processing industry.

Table 3. Number of leaves (pcs. · plant^{-1})
Tabela 3. Liczba liści (szt. · rośl.$^{-1}$)

Harvest Zbiór	Non-irrigated plants Rośliny nienawadniane	Irrigated plants Rośliny nawadniane	Mean Średnio
I harvest I zbiór	70.7 b	78.7 b	74.7 B
II harvest II zbiór	102.2 a	100.3 a	101.3 A
Mean Średnio	86.5 A	89.5 A	

Explanations see table 1 – Oznaczenia jak w tabeli 1

Table 4. The share of mass leaf blades and petioles in whole leaves of leaf celery (%)
Tabela 4. Udział masy blaszek i ogonków liściowych w całych liściach selera listkowego (%)

Harvest Zbiór	Leaf blades – Blaszki liściowe		Petiole – Ogonki	
	non-irrigated plants rośliny nienawadniane	irrigated plants rośliny nawadniane	non-irrigated plants rośliny nienawadniane	irrigated plants rośliny nawadniane
I harvest I zbiór	54.8 a	45.2 b	45.2 b	54.1 a
II harvest II zbiór	57.5 a	46.2 b	42.5 b	53.9 a
Mean Średnio	56.2 A	46.1 B	43.8 B	53.9 A

Explanations see table 1 – Oznaczenia jak w tabeli 1

Table 5. Content of dry matter in leaf blades and petioles of leaf celery, depending on irrigation and harvest time (%)
Tabela 5. Zawartość suchej masy w blaszkach i ogonkach liściowych selera listkowego w zależności od nawadniania i terminu zbioru (%)

Harvest Zbiór	Leaf blades – Blaszki liściowe		Petiole – Ogonki	
	non-irrigated plants rośliny nienawadniane	irrigated plants rośliny nawadniane	non-irrigated plants rośliny nienawadniane	irrigated plants rośliny nawadniane
I harvest I zbiór	21.10 b	17.7 c	14.60 a	10.6 b
II harvest II zbiór	24.77 a	24.38 a	13.07 a	13.03 a
Mean Średnio	22.94 A	21.04 B	13.84 A	11.82 B
Mean Średnio	21.99 A		12.83 B	

Explanations see table 1 – Oznaczenia jak w tabeli 1

Table 6. Content of total sugars in leaf blades and petioles of leaf celery, depending on irrigation and harvest time (%)
Tabela 6. Zawartość cukrów ogółem w blaszkach i ogonkach liściowych selera listkowego w zależności od nawadniania i terminu zbioru (%)

Harvest Zbiór	Leaf blades – Blaszki liściowe		Petiole – Ogonki	
	non-irrigated plants rośliny nienawadniane	irrigated plants rośliny nawadniane	non-irrigated plants rośliny nienawadniane	irrigated plants rośliny nawadniane
I harvest I zbiór	0.51 b	0.62 b	1.01 b	0.66 c
II harvest II zbiór	2.78 a	2.75 a	2.86 a	2.62 a
Mean Średnio	1.65 A	1.71 A	1.94 A	1.64 B
Mean Średnio	1.68 A		1.79 A	

Explanations see table 1 – Oznaczenia jak w tabeli 1

Table 7. Content of total chlorophyll in leaf blades and petioles of leaf celery, depending on irrigation and harvest time ($mg \cdot 100 g^{-1}$)
Tabela 7. Zawartość chlorofilu ogółem w blaszkach i ogonkach liściowych selera listkowego w zależności od nawadniania ($mg \cdot 100 g^{-1}$)

Harvest Zbiór	Leaf blades – Blaszki liściowe		Petiole – Ogonki	
	non-irrigated plants rośliny nienawadniane	irrigated plants rośliny nawadniane	non-irrigated plants rośliny nienawadniane	irrigated plants rośliny nawadniane
I harvest I zbiór	221.0 b	290.0 a	49.1 a	29.8 b
II harvest II zbiór	213.6 b	191.8 c	25.8 bc	20.6 c
Mean Średnio	217.3 B	240.85 A	37.45 A	25.2 B
Mean Średnio	229.1 A		31.3 B	

Explanations see table 1 – Oznaczenia jak w tabeli 1

Leaf celery blades contained significantly more dry matter (21.99%) compared to petioles (12.83%). A significant effect of irrigation upon dry matter content in leaf blades and petioles of celery was demonstrated during the first leaf harvest conducted in mid August, and no such effect was found during the second harvest in mid October (tab. 5).

No significant effect of irrigation was found upon total sugar content in leaf celery blades (tab. 6). Mean total sugar content was lower than that reported by Kunachowicz et al. [2005] for leaf celery (*Apium graveolens* L. var. *dulce*) and in the leaf blades it was 1.68%, and in the petioles – 1.79%. During the harvest conducted in mid August a significantly lower sugar contents were found in leaf blades and petioles, compared to the second harvest term in mid October.

Dark green, intense hue of the leaves is an important use-related feature. The leaf blades of the plants in Safir cultivar contained on average 229.1 mg · 100 g^{-1} total chlorophyll, and the petioles – 31.3 mg · 100 g^{-1} (tab. 7). During previous studies, conducted Afina cultivar plants significantly lower amount of chlorophyll was found in the leaves, respectively: in the blades: 97.0–100.7 mg · 100 g^{-1} and in the petioles 10.4–26.7 mg · 100 g^{-1} [Rożek 2007a]. The total chlorophyll content in the leaves of leaf celery (var. *secalinum*) depended upon irrigation. Leaf blades of the irrigated plants contained more of that component and the petioles had less of it, compared to non-irrigated plants.

Table 8. Content of nitrates (V) in leaf blades and petioles of leaf celery, depending on irrigation and harvest time (%)
Tabela 8. Zawartość azotanów (V) w blaszkach i ogonkach liściowych selera listkowego w zależności od nawadniania (%)

Harvest Zbiór	Leaf blades – Blaszki liściowe		Petiole – Ogonki	
	non-irrigated plants rośliny nienawadniane	irrigated plants rośliny nawadniane	non-irrigated plants rośliny nienawadniane	irrigated plants rośliny nawadniane
I harvest I zbiór	189.1 b	308.8 a	354.5 b	1172.9 a
II harvest II zbiór	55.8 d	86.7 c	224.5 c	101.3 d
Mean Średnio	122.5 B	197.8 A	289.5 B	637.1 A
Mean Średnio	160.2 B		463.3 A	

Explanations see table 1 Oznaczenia jak w tabeli 1

Table 9. Content of essential oil in air-dry leaves of leaf celery depending on irrigation and harvest time (%)
Tabela 9. Zawartość olejku eterycznego w powietrznie suchych liściach selera listkowego w zależności od nawadniania (%)

Harvest Zbiór	Non-irrigated plants Rośliny nienawadniane	Irrigated plants Rośliny nawadniane	Mean Średnio
I harvest I zbiór	0.72 a	0.58 b	0.65 A
II harvest II zbiór	0.41 c	0.42 c	0.42 B
Mean Średnio	0.57 A	0.50 A	

Explanations see table 1 – Oznaczenia jak w tabeli 1

A significant effect of irrigation upon the contents of nitrates (V) in the examined leaf elements was demonstrated. Both leaf blades and petioles contained much more nitrates (V) during harvest conducted in the first term (in mid August), compared to the second term (in mid October, tab. 8). Regardless of the harvest term, more nitrates were determined in the petioles.

The essential oil content in celery herb can range from 0.1 to 0.4% and in the leaves from 2 to 3%. During previous studies in the leaf blades of Afina cultivar plants 0.26–0.43% oil was found, whereas in the petioles: 0.09–0.25% [Rożek 2007a]. The currently obtained results indicate higher essential oil content in celery leaves, ranging from 0.41 to 0.72% (tab. 9). No effect of irrigation was demonstrated upon the essential oil content in leaf celery leaves. Mean essential oil content in air-dry herb of non-irrigated plants was slightly higher and equaled 0.57%, and in the case of irrigated plants – 0.50%. Significant differentiation occurred as to the essential oil content in the leaves collected during the first (0.65%) and second (0.42%) harvest, but it was different than in the studies by Gajc-Wolska et al. [2006] – higher oil content in leaves was found during the earlier harvest – in mid August. The author's own previous studies revealed the principal effect of weather conditions in the study years upon the accumulation of essential oils in celery leaves.

CONCLUSIONS

1. Irrigation significantly increased the height of plants, leaf celery leaf yield; nitrate contents in leaves and it also changed the proportions of leaf elements to the detriment of leaf blades.
2. No effect of irrigation was found upon the number of leaves, total sugar content in leaf blades, as well as upon the essential oil content in the whole leaves.
3. The effect of irrigation upon the dry matter content in the leaves was ambiguous. Leaf blades and petioles of the irrigated celery plants during the first harvest conducted in mid August contained less dry matter, compared to non-irrigated plants, and during the second harvest, in mid-October, no such dependence was found.
4. Harvest term significantly affected the total sugar content, nitrate (V), as well as essential oil content in leaf celery leaves. During the first harvest, conducted in mid August, the leaves contained less total sugars, but more nitrates (V) and oil.

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CZYNNIKI MODYFIKUJĄCE WIELKOŚĆ I JAKOŚĆ PLONU ORAZ SKŁAD CHEMICZNY LIŚCI SELERA LISTKOWEGO *Apium graveolens* L. var. *secalinum* Alef. UPRAWIANEGO Z ROZSADY

Streszczenie. Częścią użytkową selera listkowego są intensywnie zielone liście o silnym aromacie, wykorzystywane jako przyprawa na świeżo, po ususzeniu lub zamrożeniu. Rośliny tworzą od kilkudziesięciu do ponad stu liści, które w okresie wegetacji mogą być kilkakrotnie ścinane. Celem badań przeprowadzonych w latach 2006–2008 była ocena reakcji selera listkowego na dodatkowe nawadnianie w okresach niedoboru wilgoci w glebie. Produkcję rozsady selera rozpoczynano na początku marca, na polu rośliny sadzono w trzeciej dekadzie maja w rozstawie 25 × 25 cm. Liście zbierano dwukrotnie: w połowie sierpnia i połowie października. Wykazano istotny wpływ nawadniania na wysokość roślin, wielkość plonu ogółem selera, zawartość azotanów (V) i chlorofilu ogółem. Nawadnianie przyczyniło się do zwiększenia udziału masy ogonków liściowych i zmniejszenia udziału blaszek w masie całych liści. Nie stwierdzono wpływu nawadniania na liczbę liści, zawartość cukrów ogółem w blaszkach liściowych, a także olejku eterycznego w całych liściach. Czynnikiem istotnie modyfikującym skład liści był termin zbioru. Wpłynął on na zawartość cukrów ogółem, azotanów (V) i olejku eterycznego w liściach selera. Podczas pierwszego zbioru przeprowadzonego w połowie sierpnia liście zawierały mniej cukrów ogółem, a więcej azotanów (V) i olejku eterycznego.

Słowa kluczowe: seler listkowy, plon, nawadnianie, skład chemiczny, olejek eteryczny

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