ACTA Acta Sci. Pol., Hortorum Cultus 12(6) 2013, 227-239

EFFICIENCY OF SOME AGROTECHNICAL TREATMENTS IN QUANTITY AND QUALITY YIELD MODIFICATION OF LEAF CELERY (*Apium graveolens* L. var. *secalinum* Alef.)

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Abstract. Leaf celery (*Apium graveolens* L. var. *secalinum* Alef.) is a vegetable with spicy and medicinal properties. A study on the effect of seeding rate and irrigation on yield of two leaf celery cultivars: 'Gewone Snij' and 'Green Cuttnig', was carried out at the Felin Experimental Farm of the University of Life Sciences in Lublin during the period 2009–2010. Seeds were sown in the field in the last decade of April in rows 25 cm apart. Two seeding rates were used: 15 and 25 kg·ha^{-1}. Plant irrigation was applied during critical periods of soil water deficit. The raw material was harvested twice: in the 2nd decade of August and in the 2nd decade of October. The investigated factors were shown to have a significant effect on leaf celery yield. A significantly higher content of essential oil was found in the leaves of both celery cultivars harvested on the first date. The highest essential oil yield was obtained from irrigated plants of the cultivar 'Green Cutting' harvested in the 2nd decade of August. The main components of the essential oil of leaf celery were limonene and myrcene.

Key words: irrigation, seeding rate, industrial yield, essential oil, limonene, myrcene

INTRODUCTION

Leaf celery (*Apium graveolens* L. var. *secalinum* Alef.) is a spice plant prized for its content of volatile odorous compounds – terpenes and phthalides [Jabłońska-Ryś and Zalewska-Korona 2006, Rożek 2007a, Sowbhagya et al. 2007]. Active components contained in celery, such as sterols, glycosides, furanocoumarins, and flavonoids, exhibit a wide spectrum of action on human organism. Numerous researchers document the application of this plant in the prevention of civilisational diseases, including its valuable antioxidant properties [Jarvenpaaw et al. 1997, Kitajima et al. 2003, Momin and Nair 2002, Schmidt et al. 2008, Yildiz et al. 2008]. Atta and Alkofahi [1998] as

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well as Bonjar [2004] have also proved anti-inflammatory, analgesic, antirheumatic, and antibacterial activity of celery plants. Essential oils, found in all parts of the celery plant, contain limonene as their main constituent, but it is mainly sedanolide and other minor phthalides that give them a characteristic smell [Papamichail et al. 2000]. Limonene and myrcene, celery essential oil compounds, presented sedative and motor relaxant effects [Vale et al. 2002] and D-limonene has well-established chemopreventive activity against many types of cancer [Sun 2007]. Afec et al. [1995] as well as Pitasawat et al. [2007] have demonstrated that the substances contained in celery extracts have antifungal activity and even deter mosquitoes. Numerous authors argue that celery plants have dietetic and medicinal properties, while leaf celery is also characterized by increased vitamin C content compared to the other two botanical varieties of celery: stalk celery and celeriac [Gajc-Wolska et al. 2006, Jabłońska-Ryś and Zalewska-Korona 2006, Michalik 2002]. This vegetable is also a valuable source of mineral components: calcium, potassium, phosphorus, magnesium, iron, manganese, copper, silicon, and sodium. The developing processing industry shows an increasingly greater interest in celery [Gębczynski 2006, Hoffman 2007, Konopacka and Płocharski 2003, Polak 2008, Rumpel 2005]. This plant produces a rosette consisting of several dozen up to more than one hundred thin-stalked, dark green, pinnate leaves growing up to a height of 35–60 cm. The long growing period of this plant determines the possibility of multiple harvests and guarantees high biomass increases within one growing season.

Celery belongs to vegetables with high water requirements. It often happens that the amount of rainfall in Poland does not meet the water requirement of this plant [Rożek 2005a, 2006, 2007b, Rożek et al. 2012, Rumasz-Rudnicka 2008]. Leaf celery can be grown from seedlings using a quite cost-consuming and more reliable method (150.000–200.000 $pcs \cdot ha^{-1}$) or by direct field seeding which, under favourable soil moisture conditions, gives comparably good results and reduces production costs [Rożek 2005b, 2006]. It seems important to develop methods that would improve uneven, poor, and slow emergence of this plant, caused in particular by adverse soil and climatic conditions, not only through presowing seed priming but also through other factors that would guarantee the reliability of this type of crop [Borowski and Michałek 2006]. Deficit irrigation usually entails a risk of negative impacts to the yield quantity and quality of more vegetables and medicinal plants. Climate conditions had a significant effect on the essential oil production in Apiaceae family [Olle and Bender 2010]. Water deficit results in decrease of mint plant growth, herb yield, essential oil accumulation and alters plant morphology [Kołodziej 2008, Okwany et al. 2011], likewise reduced anise oil production [Zehtab-Salmasi et al. 2001]. Drought stress may increased secondary metabolites in medicinal plants [Abreu and Mazzafera 2005, Khalid 2006, Azimi et al. 2012]. Moreover, increasing the period between irrigation gave the highest relative constituents of the most important compounds of thyme essential oil [Aziz et al. 2008]. Water stress imposed by restricting the number of irrigation increased the volatile oil content in parsley and fennel [Mohamed and Abdu 2004, Petropoulos et al. 2008] and at the same time fennel oil yield increased with irrigation [Mohamed and Abdu 2004]. Irrigation increased essential oil content of coriander seeds and decreased linalool concentration [Arganosa et. al 1998]. Therefore, the aim of the present study was to evaluate the effect of seeding rate and irrigation on yield and yield quality of two leaf celery cultivars.

MATERIALS AND METHODS

The experiment was conducted at the Felin Experimental Farm of the University of Life Sciences in Lublin (51º14'N, 22º38'W) during the period 2009–2010. Plants of two leaf celery cultivars: 'Gewone Snij' and 'Green Cuttnig', were the subject of the study. 120 kg ha^{-1} N in the form of ammonium nitrate, 100 kg·ha^{-1} P_2O_5 in the form of triple superphosphate, and 150 kg·ha^{-1} K_2O as potassium sulphate were applied in the spring before sowing. Celery seeds were sown in the field on 28 April in rows 25 cm apart, in 2.5 m^2 plots. The experiment was conducted in four replications. Two seeding rates: 15 kg·ha^{-1} and 25 kg·ha^{-1}, were used in the experiment. During critical periods of soil water deficit, plants were irrigated with a single water dose of 15–20 mm. Irrigation was used five times in 2009 and six times in 2010. Emergence of irrigated plants occurred more than a week earlier (28 May in 2009, 5 June in 2010) compared to non-irrigated plants (5 June in 2009, 15 June in 2010). Observations of plant emergence were carried out until 26 June in 2009 and until 3 July in 2010. Tending and protection treatments recommended for this species were performed. Agronomic investigations included the determination of the rate of germination and plant growth as well as leaf yield. The raw material was harvested twice: in the 2nd decade of August and in the 2nd decade of October. During harvest, leaves were cut off 3–5 cm above ground. After the first harvest, nitrogen fertilization was applied at a rate of 40 kg·ha^{-1}.

In air-dried herb of leaf celery, the essential oil content was determined using a Deryng apparatus by the steam distillation method according to Polish Pharmacopoeia VII [2006], while the content of individual components of this oil was determined by gas chromatography (GC/MS). The extracted essential oil was stored in a dark glass container at a temperature of -10ºC, until the time of chromatographic separation. Qualitative and quantitative analysis of the coriander essential oil was performed using a ITMS Varian 4000 GC-MS/MS (Varian, USA) GC-MS instrument, equipped with a CP-8410 auto-injector and a 30 m × 0.25 mm i.d. VF-5ms column (Varian, USA), film thickness 0.25 µm; carrier gas, helium at a rate of 0.5 ml min^{-1}; injector and detector temperature, 250ºC; split 1:100. 1 µl of the solution was injected (10 µl of the sample in 1000 µl of hexane). A temperature of 50ºC was applied for 1 min, then it was incremented to 250ºC at a rate of 4ºC·min^{-1}; 250ºC was applied for 10 min. A VF-5 ms column was used. Helium was the carrier gas, with a constant flow of 0.5 ml·min^{-1}. Injector: 250ºC; split 1:100. 1 µl of the solution was injected (10 µl of the sample in 1000 µl of hexane). A Varian 4000 MS/MS detector was used, recorded range: 40–1000 m/z, scan rate 0.8 sec/scan. The retention indices were determined based on the alkane series C_6-C_{40}. The qualitative analysis was carried out on the basis of MS spectra, which were compared with the spectra of the NIST library [Mass Spectral Library 2008] and with data available in the literature. The identity of the compounds was confirmed by their retention indices, taken from the literature [Adams 2004] and own data. The results of the study were statistically analysed using analysis of variance for two-way and three-way classification. The significance of differences was calculated by Tukey's multiple confidence intervals at the confidence level of 5%.

RESULTS AND DISCUSSION

The existing research on yield of direct seeded leaf celery has shown that yield can be influenced by controlling relevant agronomic factors such seeding rate, plant density, and irrigation [Rożek 2005a, b, 2006]. During the present study, emergence of leaf celery was dependent on weather conditions in early spring. In 2009, in spite of a small amount of rainfall at the beginning of May (tab. 1), better plant emergence was obtained than in 2010 (tab. 2). This resulted from heavy (106.7 mm) rainfall events in the second decade of May which eroded the soil structure and impeded emergence. Yield of direct seeded vegetables is directly dependent on good plant emergence. Plant density per 1 running meter (rmt) was satisfactory in both study years in both irrigated (145.5–294.5 pcs. rmt^{-1}) and non-irrigated plots (284.3–404.6 pcs. rmt^{-1}). During a similar study conducted in the period 2004–2005 [Rożek 2006], celery emergence was much worse: in non-irrigated plots plant density was from 7.2 to 11.3 pcs rmt^{-1}, while in irrigated ones from 13.6 to 155.6 pcs rmt^{-1}. Irrespective of the other experimental factors, an increase in seeding rate from 15 $kg \cdot ha^{-1}$ to 25 $kg \cdot ha^{-1}$ resulted in a significant increase in plant density in each treatment. Seeds of the cultivar 'Green Cutting' germinated better each year.

Table 1. The 10-day, monthly and multi-year monthly totals of precipitation in Felin in 2009, 2010 (multi-year average in 1951–2005)

Month	2009				2010				Multi-year monthly totals
	10-days totals			monthly totals	10-day totals			monthly totals	
	I	II	III		I	II	III		
April	1.1	1.8	0	2.9	13.8	7.7	3.0	24.5	40.2
May	3.6	34.7	32.9	71.1	39.7	106.7	10.3	156.7	57.7
June	28.2	32.9	64.6	125.5	34.6	30.2	0.8	65.6	65.7
July	15.6	9.8	31.7	57.1	15.3	9.8	75.9	101.0	83.5
August	16.2	29.9	8.6	54.7	65.6	6.9	60.3	132.8	68.6
September	11.3	0.9	8.8	21.0	80.8	10.6	28.0	119.0	51.6
October	20.2	54.9	28.5	103.6	1.5	7.3	2.4	11.2	40.1

Leaf celery grown from seedlings can be cut several times during the growing period of plants. Two or three harvests are used most frequently. In the case of direct seeded plants, it is possible to do one or two harvests if plants are not irrigated [Rożek 2005a, b, 2006, 2007b]. In the present study, in 2009 irrigated plants reached the optimal height during the first and second harvest, whereas in 2010 they were much lower during the second harvest (tab. 3). In both study years, non-irrigated plants did not reach the optimal height during the second harvest in all treatments. The average plant height of non-irrigated plants was 27.8 cm in 2009 and 23.6 cm in 2010, while for irrigated plants it was 47.4 cm in 2009 and 30.7 cm in 2010.

Table 2. Influence of seeding rate and irrigation on emergence for leaf celery (pcs.·rmt[1])

Cultivar	Seeding rate (kg·ha^{-1})	2009		2010	
		non-irrigatedplants	irrigated plants	non-irrigatedplants	irrigated plants
Gewone Snij	15	184.7	315.0 b	127.7	266.7 b
	25	321.0	494.3 a	163.3	302.0 a
	mean	252.8 B	404.6 A	145.5 B	284.3 A
Green Cutting	15	226.3	331.3 b	160.3	247.3 b
	25	362.7	476.7 a	270.0	338.7 a
	mean	294.5 B	404.0 A	215.2 A	293.0 A
Mean for seeding rate	15	205.5 B	323.2 B	144.0 B	257.0 A
	25	341.8 A	485.5 A	216.6 A	320.3 A
Mean for irrigation		273.7 B	404.3A	180.3 B	288.6 A

values marked with the same letter do not differ significantly at α = 0.05

Table 3. Influence of seeding rate and irrigation on plant height of leaf celery (cm)

Cultivar	Irrigation	Seeding rate (kg·ha^{-1})	Plant height (cm)			
			2009		2010	
			first harvest	second harvest	first harvest	second harvest
Gewone Snij	non-irrigated plants	15	35.6	14.0	40.0	15.0
		25	39.0	15.0	35.0	11.0
	irrigated plants	15	50.0	52.0	50.0	17.0
		25	40.0	48.0	45.0	13.0
Mean			36.7 A		28.2 B	
Green Cutting	non-irrigated plants	15	39.0	21.0	40.0	11.0
		25	42.0	17.0	30.0	7.0
	irrigated plants	15	45.0	52.0	45.0	19.0
		25	43.3	49.0	43.0	14.0
Mean			38.5 B		26.1 A	
Mean for irrigation		non-irrigated plants	27.8 A		23.6 A	
		irrigated plants	47.4 B		30.7 B	
Mean for seeding rate		15	38.6 B		29.6 B	
		25	36.7 A		24.7 A	
Mean for date of harvest		first harvest (August)	41.7 B		41.0 B	
		second harvest (October)	33.5 A		13.4 A	

values marked with the same letter do not differ significantly at α = 0.05

The better emergence of celery in 2009, in comparison to 2010, translated into better yield. Leaf yield harvested in the first year, depending on the cultivar and irrigation, ranged from 4.14 kg·m^{-2} to 4.93 kg·m^{-2} during the first harvest, whereas during the second harvest it was from 2.25 kg·m^{-2} to 6.37 kg·m^{-2} (fig. 1). Leaf yield ranging from 2.44 kg·m^{-2} to 3.59 kg·m^{-2} was obtained from plants grown in the second year during the first harvest, while during the second harvest it was from 1.32 kg·m^{-2} to 3.48 kg·m^{-2}. Irrigation was shown to have a significant effect on total leaf yield of leaf celery in both study years. Irrespective of the cultivar and seeding rate, the average total leaf yield during the study years (tab. 4) was 5.35 kg·m^{-2} for non-irrigated plants, whereas in the case of irrigated plants it was 8.70 kg·m^{-2}. The study demonstrated a significant effect of cultivar, seeding rate, and irrigation on leaf celery yield. The highest yield was obtained from irrigated plants of the cultivar 'Gewone Snij' at the seeding rate of 25 kg·ha^{-1}.

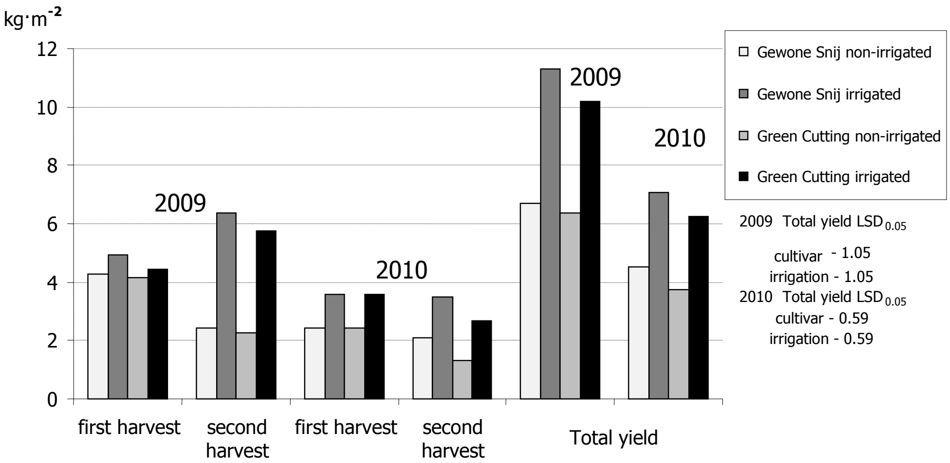

Fig. 1. Yield of leaf celery collected during the first (II decade August) and second (II decade October) date of harvest depending on irrigation

The next stage of the study was to evaluate the content and chemical composition of the essential oil in air-dried herb of celery (tabs 5–7). In non-irrigated plants, the oil content ranged 0.29–0.57%, whereas in irrigated plants 0.24–0.66%. Celery leaves harvested in August were characterized by a higher content of essential oil (on average for the cultivars 0.57% of air-dry weight compared to those picked in October (0.30%), which confirm the earlier study results [Rożek et al. 2012]. The essential oil content determined in air-dried herb was by far higher than that shown by Gajc-Wolska et al. [2006] (0.16%) and only slightly higher than the one obtained by Rożek [2007a] (0.43%). Irrigation was not found to have a significant influence on essential oil content in celery plants. Similar findings were obtained in the earlier experiments [Rożek et al.

2012]. Drought stress increases the essential oil of more medicinal plants, because of the increased production of more metabolites. Basil essential oil production, as well as its main constituents, proline and total carbohydrate content increased in response to water stress [Khalid 2006]. Differently, essential oil content was higher in the irrigated peppermint plants then in non-irrigated ones [Kołodziej 2008]. Well irrigated marigold plants led to the highest essential oil content [Azimi et al. 2012]. On the contrary, essential oil yields in thyme plants decreased with increasing the irrigation period. Moreover, the phenolic compound (thymol) content in thyme oil increase under the stress condition [Aziz et al. 2008]. Total peppermint oil yields showed a low sensitivity to water stress at moderate stress levels; the decrease in herb yield with water stress was much greater than with oil yield [Okwany et al. 2011].

Table 4. Influence of seeding rate and irrigation on industrial yield leaf celery (2009–2010)

Cultivar	Seeding rate ($kg \cdot ha^{-1}$)	Industrial yield ($kg \cdot m^{-2}$)		Mean
		non-irrigated	irrigated plants	
Gewone Snij	15	5.05 a	8.87 b	6.96 a
	25	6.17 a	9.49 b	7.83 b
	mean	5.61 A	9.18 B	7.40 B
Green Cutting	15	4.61 a	8.20 b	6.40 a
	25	5.55 a	8.25 b	6.90 a
	mean	5.08 A	8.23 B	6.65 A
Mean for seeding rate	15	4.83 A	8.54 B	6.68 B
	25	5.86 A	8.87 B	7.37 A
Mean for irrigation		5.35 A	8.70 B	7.02

values marked with the same letter do not differ significantly at $\alpha = 0.05$

Table 5. Influence of date of harvest and irrigation on essential oil content in air dry weight of leaf celery (2009–2010)

Cultivar	Date of harvest	Essential oil content (%)		Mean
		non-irrigated	irrigated plants	
Gewone Snij	II decade August	0.56 b	0.56 d	0.56 b
	II decade October	0.29 a	0.36 b	0.32 a
	mean	0.42 A	0.46 A	0.44 A
Green Cutting	II decade August	0.57 b	0.66 c	0.61 b
	II decade October	0.35 a	0.24 a	0.29 a
	mean	0.46 A	0.45 A	0.45 A
Mean for date of harvest	II decade August	0.57A	0.61B	0.58B
	II decade October	0.32A	0.30A	0.30A
Mean for irrigation		0.44A	0.45A	0.44

values marked with the same letter do not differ significantly at $\alpha = 0.05$

Table 6. Influence of cultivar and date of harvest on composition of essential oil in air dry weight herb of non-irrigated leaf celery (2009–2010)

No	Component	RI	Composition of essential oil (%)							
			2009				2010			
			Gewone Snij		Green Cutting		Gewone Snij		Green Cutting	
			first harvest 17.08	second harvest 19.10	first harvest 17.08	second harvest 19.10	first harvest 18.08	second harvest 20.10	first harvest 18.08	second harvest 20.10
1	α-pinene	935	–	–	–	–	tr.	–	0.07	0.21
2	camphene	951	–	–	–	–	–	–	–	tr.
3	sabinene	976	–	–	–	–	0.07	–	0.10	0.14
4	β-pinene	981	–	0.37	0.34	0.34	0.14	0.50	0.18	0.38
5	**myrcene**	991	**39.94**	**35.65**	**40.12**	**34.55**	**44.60**	**29.29**	**38.49**	**31.77**
6	α-terpinene	1023	–	–	–	–	–	–	tr.	
7	δ-cymene	1026	0.37	0.42	0.34	0.35	0.20	0.43	0.21	0.22
8	**limonene**	1031	**38.48**	**48.58**	**43.40**	**51.98**	**45.89**	**53.06**	**52.70**	**46.36**
9	(Z) β-ocimene	1036	2.89	3.63	2.85	2.89	2.75	7.76	3.61	8.90
10	(E) β-ocimene	1046	–	–	–	–	0.05	–	0.07	0.21
11	γ-terpinene	1058	1.83	1.59	1.87	1.65	1.58	2.99	1.96	2.96
12	6-butyl-1,4-cycloheptadiene	1161	–	–	–	–	0.22	–	0.20	0.37
13	geijerene	1167	–	–	–	0.30	–	–	–	–
14	carvacrol	1291	–	–	–	–	0.25	–	–	–
15	E-caryophyllene	1436	2.44	0.83	2.44	0.91	1.42	2.18	0.87	0.92
16	n.i.	1439	–	–	–	–	–	0.58	–	–
17	α-humulene	1476	–	–	–	–	0.10	–	0.07	0.08
18	γ-curcumene	1495	0.30	–	–	–	0.08	–	tr.	–
19	β-selinene	1511	3.84	1.88	3.54	1.66	1.84	2.31	1.20	1.76
20	α-selinene	1519	0.52	–	0.49	–	0.30	0.43	0.20	0.22
21	kessane	1550	–	–	–	0.32	tr.	–	tr.	0.17
22	α-santoline alcohol	1649	0.18	–	–	–	–	–	–	–
23	n.i.	1658	–	–	–	–	–	–	–	0.15
24	2,5-pyrrolidinedione,1-[(3,4dimethylbenzoyl)oxy]	1676	2.01	2.40	1.17	1.99	tr.	–	–	0.14
25	n.i.	1705	0.30	0.32	–	0.33	0.08	–	–	0.09
26	α-pentyl-benzenemethanol	1712	–	–	–	–	0.17	–	–	4.08
27	2,2-dimetyl-1-phentyl-propanol	1732	0.76	1.10	–	2.38	–	–	–	–
28	furan, 2-(2-propenyl)	1738	3.92	3.23	1.76	0.36	–	–	–	–
29	Z-ligustilide	1758	–	–	–	–	–	0.26	–	0.41
30	n.i.	1841	2.21	–	1.68	–	0.14	0.21	–	0.42

n.i. – unidentified compound, tr. – contents below 0.05%

Table 7. Influence of cultivar and date of harvest on composition of essential oil in air dry weight herb of irrigated leaf celery (2009–2010)

No	Component	RI	Composition of essential oil (%)							
			2009				2010			
			Gewone Snij		Green Cutting		Gewone Snij		Green Cutting	
			first harvest 17.08	second harvest 19.10	first harvest 17.08	second harvest 19.10	first harvest 18.08	second harvest 20.10	first harvest 18.08	second harvest 20.10
1	α-pinene	939	–	–	–	–	0.06	0.30	0.05	0.25
2	camphene	955	–	–	–	–	–	0.06	–	0.06
3	sabinene	980	–	–	–	–	0.08	0.12	0.09	0.14
4	β-pinene	985	0.18	0.30	–	0.53	0.17	0.38	0.21	0.33
5	**myrcene**	992	**32.25**	**43.65**	**28.11**	**33.39**	**39.27**	**35.26**	**37.59**	**29.17**
6	α-terpinene	1022	–	–	–	–	–	–	tr.	–
7	δ-cymene	1030	0.54	0.32	0.26	0.71	0.27	0.24	0.18	0.28
8	**limonene**	1036	**46.49**	**40.35**	**51.30**	**43.08**	**51.14**	**46.68**	**50.99**	**51.52**
9	(Z) β-ocimene	1042	5.29	2.71	1.56	5.34	4.00	9.10	4.65	9.42
10	(E) β-ocimene	1049	–	–	–	–	0.08	0.18	0.08	0.18
11	γ-terpinene	1062	3.08	1.59	2.76	3.73	1.85	2.66	2.15	3.00
12	6-butyl-1,4-cycloheptadiene	1165	–	–	–	–	0.26	0.20	0.22	0.28
13	geijerene	1171	–	0.24	–	0.22	–	–	–	–
14	carvacrol	1325	–	–	–	–	–	–	0.06	
15	E-caryophyllene	1434	1.16	1.68	2.71	1.84	0.88	0.82	0.81	1.13
16	α-humulene	1480	–	–	–	–	0.07	0.06	0.06	0.10
17	γ-curcumene	1503	–	0.29	–	0.26	0.05	0.15	0.07	0.12
18	AR-curcumene	1505	–	–	–	–	–	0,07	–	–
19	β-selinene	1507	1.96	2.59	5.24	3.20	1.11	1.50	1.28	1.67
20	α-selinene	1518	–	0.34	0.61	0.42	0.19	0.27	0.22	0.33
21	β-curcumene	1531	–	–	–	–	–	–		0.05
22	kessane	1457	0.44	–	0.69	0.11	tr.	0.14	0.06	0.14
23	4-methyl-trans-3-oxabicyclo[4,4,0]decane	1661	–	–	–	–	–	0.18	0.05	0.09
24	caryophyllene oxide	1601	–	–	0.58	–	–	–	–	–
25	n.i.	1652	–	–	–	0.60	–	–	–	–
26	α-santoline alcohol	1648	0.37	0.26	–	–	–	–	–	–
27	2,5-pyrrolidinedione,1-[(3,4-dimethylbenzoyl)oxy]	1663	1.51	1.11	2.10	1.44	0.07	0.41	0.14	0.30
28	3-Z-butylidene phthalide	1691	–	–	–	–	–	–	–	0.06
29	n.i.	1689	0.38	0.33	–	0.34	0.11	0.17	0.16	0.09
30	2,2-dimetyl-1-phentyl-propanol	1736	–	0.37	–	0,48	–	–	–	–
31	α- pentyl-benzenemethanol	1756	–	–	–	–	0.14	0.85	0.72	0.93
32	furan, 2-(2-propenyl)	1738	6.34	2.93	4.07	3.11	–	–	–	–
33	Z-Ligustilide	1761	–	–	–	–	tr.	–	–	–
34	n.i.	1834	–	0.94	–	1.20	0.13	0.18	0.14	0.35

n.i. – unidentified compound, tr. – contents below 0.05%

The percentages of individual chemical components in celery oil are variable and depend on many factors, both genetic and environmental ones, as well as on the marketable part of the plant from which they are derived [Rożek, 2007a, Sowbhagya et al. 2007, Wolski et al. 2001, Yildiz et al. 2008]. Bicchi et al. [1999] argue that the application of various gas chromatography techniques to determine the content of chemical compounds in celery oil shows differences in the number of isolated compounds. 12–24 compounds were identified in the oil of leaf celery, depending on experimental factors. The main constituents of the oil distilled from air-dried herb of leaf celery were as follows: limonene (38.48–53.06%), myrcene (28.11–44.60%), (Z) β-ocimene (1.56–9.42%), β-selinene (1.11–5.24%), γ-terpinene (1.58–3.08%), E-caryophyllene (0.81–2.71%), furan, 2-(2-propenyl) (0.36–6.34%), 2,5-pyrrolidinedione,1-[(3,4-dimethylbenzoyl)oxy] (0.05–2.40%) (tab. 6–7). Among all 34 identified compounds contained in the oils, seven were constant and found in all treatments (limonene, myrcene, (Z)-β-ocimene, β-selinene, γ-terpinene, E-caryophyllene, δ-cymene), whereas the other components changed depending on experimental factors.

Higher amounts of components contained in the essential oil were found in plants grown in the second year of the experiment. The research on the composition of leaf celery conducted by Rożek [2007a] showed the presence of the following compounds: limonene, pseudolimonene, γ-terpinene, cubebol, α-pinene, β-pinene and E-caryophyllene. Wolski et al. [2008] confirm that myrcene and β-selinene appear as the main components in celery oils. The remaining active substances found in small amounts were the following: camphene, sabinene, (E)-β-ocimene, β-pinene, α-humulene, γ-curcumene, β-selinene, α- selinene, kessane, caryophyllene oxide, 3-Z-butylidene phthalide, Z-ligustilide, similarly as in the studies of Rożek [2007a] and Wolski et al. [2008]. The contents of the above-mentioned components was different in the leaves of plants collected during the first and second harvest, as well as in the leaves of irrigated and non-irrigated plants (tab. 6–7). It should be noted that changes in the main compounds concentration may indicated a greater influence of genetic and environmental factors (cultivar, year of cultivation) then agrotechnical ones (harvest term, irrigation). The limonene and myrcene concentration was greater in the leaves of 'Green Cutting' then 'Gewone Snij'plant's. Limonene concentration was comparable in leaves collected during the first and second harvest and from the irrigated and non-irrigated plants. Differently myrcene concentration was greater in the first harvest term and non-irrigated plants, then in another ones. Water stress treatments slightly modified limonene and myrcene content in basil essential oil [Khalid 2006]. Okwany et al. [2011] reported a 0.5% decrease in the myrcene and a 5% increase in limonene content in spearmint oil with increased water stress, which indicates that water-stressed plants may be less mature as limonene is a precursor to carvone. Above differences were probably due to genetic and ontogenetic variability of essential oil biosynthesis.

CONCLUSIONS

1. The present study showed a positive effect of increased seeding rate and irrigation on emergence and yield of leaf celery. Irrigation had a greater influence on the evaluated growth parameters and yield of plants compared to seeding rate.
2. Higher leaf yield was obtained from plants of the cultivar 'Gewone Snij', then from 'Green Cutting'.
3. Irrigation and cultivar were not shown to have a significant effect on leaf essential oil content in leaf celery.
4. Time of leaf harvest was shown to significantly affect leaf essential oil content. Leaves harvested in the 2nd decade of August contained much more oil compared to those picked in the 2nd decade of October.
5. The main components of leaf celery essential oil were limonene, myrcene, (Z)-β-ocimene, β-selinene, γ-terpinene, and E-caryophyllene. Our results show that it is possible to modify the composition of leaf celery essential oil by manipulating agricultural techniques such as seeding rate and irrigation.

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EFEKTYWNOŚĆ NIEKTÓRYCH ZABIEGÓW AGROTECHNICZNYCH W KSZTAŁTOWANIU WIELKOŚCI I JAKOŚCI PLONU SELERA LISTKOWEGO (*Apium graveolens* L. var. *secalinum* Alef.)

Streszczenie. Seler listkowy *Apium graveolens* L. var. *secalinum* Alef. jest warzywem przyprawowym o właściwościach leczniczych. W latach 2009–2010 w Gospodarstwie Doświadczalnym Felin Uniwersytetu Przyrodniczego w Lublinie przeprowadzono badania nad wpływem normy siewu i nawadniania na plonowanie dwóch odmian selera listkowego: Gewone Snij i Green Cuttnig. Nasiona wysiano na polu rzędowo, co 25 cm, w ostatniej dekadzie kwietnia. Zastosowano dwie normy siewu: 15 i 25 $kg \cdot ha^{-1}$. W krytycznych okresach niedoboru wody w glebie stosowano nawadnianie roślin. Zbiór surowca przeprowadzono dwukrotnie: w II dekadzie sierpnia i II dekadzie października. Wykazano, że badane czynniki, tj. norma siewu, odmiana i nawadnianie miały istotny wpływ na wielkość plonu selera listkowego. Termin zbioru ziela miał istotny wpływ na zawartość olejku eterycznego. Największy plon olejku eterycznego uzyskano z nawadnianych roślin odmiany Green Cutting, zbieranych w II dekadzie sierpnia. Głównymi składnikami olejku były limonen i mircen.

Słowa kluczowe: nawadnianie, norma siewu, plon przemysłowy, olejek eteryczny, limonen, mircen

Accepted for print: 1.08.2013