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INFLUENCE OF PLANT DENSITY AND TERM OF HARVEST ON YIELD AND CHEMICAL COMPOSITION OF SWEET MARJORAM (*Origanum majorana* L.)

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Abstract. The experiments carried out in 2006–2007 referred to the growth of marjoram plants, its yields and chemical composition depending on the plant density and harvest time. Four plant densities (setting spacing 20 × 40 cm, 30 × 30 cm, 30 × 40 cm and 40 × 40 cm) as well as two harvest times (beginning of flower bud forming and full blooming) were applied. The lowest density favored the plant tillering, which apparently affected the herb yield. Plants growing at the lowest density (40 × 40 cm spacing) had the largest fresh and air-dried herb yields (0.71 and 0.18 kg m^{-2}, respectively). Herb of plants grown at denser spacing contained more total nitrogen and nitrates (V) as well as less potassium, than that of plants grown at lower density. The herb harvest at full flowering stage turned out to be favourable because of significantly lover nitrates concentration as compared to other stages. The contents of essential oil was significantly higher in the full flowering stage than in those harvested in the bud formation stage. Plants growing at denser spacing produced more oil. Trans-sabinene hydrate and terpinene-4-ol were dominating components of marjoram essential oil.

Key words: Origanum majorana, sweet marjoram, yield and chemical composition of herb, marjoram essential oil

INTRODUCTION

Marjoram (*Origanum majorana* L.) is cultivated for pharmaceutical and consumption purposes in many European, Asian and North-American countries. It originates from the Mediterranean, East, and India areas. Under climatic conditions in Poland, it is an annual plant. Marjoram has great light, thermal, and nutritive requirements, and is counted as a plant with moderate water requirements. In Poland, it is a well-known herb

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cultivated from a direct sowing or a seedling grown in a greenhouse. Although setting the marjoram plantation by means of direct seed sowing in the field takes less labor, it makes the yields more dependent on the weather. Setting the seedling, the vegetation period can be prolonged and its initial stages can be independent of unfavorable weather conditions. The marjoram herb is harvested since the occurrence of first flower buds. It contains up to 3% essential oil with antibacterial, insecticidal, and fungicidal properties, which are utilized in pharmacy, foodstuff, cosmetic, and perfumery industries [Deans and Svoboda 1990, Barrata et al. 1998, De Vincenzi et al. 2004, Vági et al. 2005]. Compositions of marjoram oil originating from different species, varieties, and cultivation sites are different, which was the subject of numerous studies [Nykanen 1986, Lawrence 1989, Vera and Chane-Ming 1999, Novak et al. 2000, Tabanca et al. 2004, Seidler-Łożykowska 2007, Zawiślak 2008]. Góra and Lis [2005] reported that marjoram oils are characterized by great variability of chemical composition, and cultivated varieties can be counted to various chemotypes: terpineloic, sabinolic, mixed, linalolic, and carvacrolic.

The research aimed at evaluating the growth and yields of marjoram herb depending on the plant density and harvest time. Quantitative and qualitative composition of essential oil at two development stages, as well as contents of minerals in herb were determined.

MATERIAL AND METHODS

The experiments were carried out in 2006–2007. The sweet marjoram was grown from the seedling produced in a greenhouse at The Experimental Farm Felin. The field experiment was set as bi-factorial by means of randomized blocks in four replications. Plant density (setting spacing 20 × 40 cm, 30 × 30 cm, 30 × 40 cm and 40 × 40 cm) as well as harvest time depending on plant's development stage (beginning of flower bud forming and full blooming) were experimental factors. Seeds were sown at the beginning of March, while plants were set into the field at about mid of May. Depending on the plant density, area of particular plot was 1.68 m^2, 2.52 m^2, 3.40 m^2 or 1.90 m^2. The following mineral fertilization was applied: 70 kg N ha^{-1} (in two doses: before setting and two weeks after the root-taking of plants) in a form of ammonium nitrate 34%, 50 kg P_2O_5 ha^{-1} as superphosphate 20% and 100 kg K_2O ha^{-1} as potassium sulphate. Manual and mechanical plant weed control and mulching of interspaces was made during the vegetation period, while measurements of plant's height and diameter, counting of shoots and branches on the main shoot number, as well as buds and inflorescences on a main shoot on 12 randomly selected plants were made before harvest.

The marjoram herb was harvested twice: at the second decade of June (flower bud stage) and at the first decade of July (full of blooming). Just after the harvest, weight of fresh herb was determined, and then, after drying under natural conditions, air-dried weight of herb was evaluated. Plant material dried at 70°C was subjected to determinations of N-total content by means of Kjeldahl's method on automated Kjel-Foss device; ammonia and nitrates (V) were analyzed applying Bremner's distillation method with Starck's modifications in 2% CH_3COOH extract; chlorides – with $AgNO_3$; and sulfates

– nephelometry with $BaCl_2$. After combusting at 550°C, phosphorus was determined by means of colorimetry with ammonium; and potassium, calcium, and magnesium – AAS technique (Perkin-Elmer Analyst 300). Achieved results were statistically processed by means of variance analysis for double classification at the significance level of $\alpha = 0.05$. Air-dried marjoram herb was distilled with steam to obtain essential oil. The qualitative and quantitative composition of produced oil was determined by means of gas chromatography coupled with mass spectrometry (GC/MS). Determinations were performed using Varian 4000 Mass Spectrometr with column VF-5 ms (30 m length, 0.25 mm diameter, 0.25 mm stationary phase thickness). The injector temperature – 220°C. The temperature gradient was: 60°C for 5 min., then increment 60–246°C (3°C/min) and 246°C for 10 min. The quantitative analysis consisted in comparing the achieved mass spectra with those from NIST and LIBR libraries (Finnigan MAT company). Unknown compounds were identified using published mass spectra and retention indices.

RESULTS

The weather in 2006 and 2007 favored marjoram's growth and development (tab. 1). Air temperature during the plant setting and their vegetation sometimes exceeded the mean values from 45 year period, which made a convenient conditions for a plant with great thermal requirements, i.e. for marjoram. And similarly, a proper rainfalls level, namely at the beginning of plant's growth, favored their vegetation. Lack of rainfall in the second decade of June and at the first decade of July, as well as a small amount of precipitation in the last decade of June 2006 should be noticed, which could have disturbed the harmonious growth and development of plants.

Table 1. Weather conditions. Air temperature and total precipitation in 2006 and 2007 years against a background of many-year averages

Tabela 1. Warunki pogodowe. Średnia temperatura powietrza oraz sumy opadów w latach 2006 i 2007 na tle średnich wieloletnich

	Month Miesiąc	2006				2007				1951–1995
		decade – dekada			mean średnio	decade – dekada			mean średnio	
		I	II	III		I	II	III		
Temeperature	V	13.5	14.6	12.8	13.6	9.9	15.1	19.6	14.9	13.0
Temperatura	VI	11.6	17.9	21.1	16.9	18.2	20.0	16.2	18.1	16.4
°C	VII	21.2	20.8	23.5	21.9	17.1	21.0	19.3	19.1	17.9
Precipitation	V	9.0	18.4	32.1	59.5	13.5	29.9	37.1	80.5	57.2
Opady	VI	28.4	0.0	9.5	37.9	52.4	25.4	10.0	87.8	65.9
mm	VII	0.0	6.8	0.0	6.8	48.8	35.0	3.2	87.0	73.6

Studied marjoram plants reached mean height of 31.5 cm and diameter of 32.6 cm (tab. 2). Plants growing at the highest density (30 × 30 cm spacing) were the highest, but the differences were not statistically significant. Plants growing in the lowest density (40 × 40 cm spacing) were characterized by the largest diameter (38.0 cm). A significant influence of the harvest date, determined by the development stage, on their examined morphological traits was reported. The marjoram plants harvested at flower bud forming stage had considerably shorter shoots, as well as fewer steams and branches as compared to those at full flowering stage. Herb from plants cultivated at looser density had more flower buds and inflorescences than other ones (tab. 2).

Table 2. Morphological characteristics of marjoram plants (mean of 2006 and 2007)
Tabela 2. Charakterystyka morfologiczna roślin majeranku (średnio z 2006 i 2007)

Plant spacing Rozstawa sadzenia cm	Harvest time Termin zbioru	Plant height Wysokość rośliny, cm	Plant diameter Średnica rośliny cm	Shoot number per plant Liczba pędów z rośliny	Branches number of main shoot Liczba rozgałęzień pędu głównego	Buds and inflorescences number of main shoot Liczba pąków i kwiatostanów na pędzie głównym
20×40	I	29.1	25.6	6.5	12.0	51.6
	II	32.2	31.6	7.2	14.3	100.7
Mean – Średnio		30.7	28.6	-	-	-
30×30	I	32.2	29.6	6.9	13.4	61.2
	II	34.0	35.2	7.4	14.6	87.5
Mean – Średnio		33.1	32.4	-	-	-
30×40	I	29.2	29.6	6.7	12.8	67.8
	II	33.6	33.4	8.2	14.9	112.8
Mean – Średnio		31.4	31.5	-	-	-
40×40	I	28.8	32.7	7.0	13.7	76.4
	II	32.9	43.3	9.1	15.9	123.5
Mean – Średnio		30.8	38.0	-	-	-
Mean harvest time Średnio termin zbioru	I	29.9	29.4	6.8	13.0	64.3
	II	33.2	35.9	8.0	14.9	106.1
Mean – Średnio		31.5	32.6	-	-	-
LSD – $NIR_{0.05}$:						
plant spacing – rozstawa sadzenia		n.s.	7.7	-	-	-
harvest time – termin zbioru		2.6	4.8	-	-	-
interaction – współdziałanie		n.s.	n.s.	-	-	-

I – the second decade of June – druga dekada czerwca
II – the first decade of July – pierwsza dekada lipca

Yield of fresh and air-dried marjoram herb significantly depended on studied factors (tab. 3). The largest yields of fresh and dry herb (0.71 and 0.18 kg m^{-2}, respectively) were achieved from plants grown at the smallest density, and differences between mean values of these traits for plants from the greater and smaller density were not statistically significant. Yield of plants harvested at full flowering stage was considerably higher than those at flower bud stage. Interaction between studied factors was significant. The average essential oil content was 1.63% and it significantly depended on plant harvest date (tab. 3). Marjoram harvested at full blooming stage was characterized by higher oil content (1.74%) as compared with plants forming flower buds (1.51%). The marjoram density had not any significant influence on the amount of produced essential oil, although its largest quantities (1.68%) were found at plants growing at the smaller spacing.

Analysis of chemical composition of marjoram herb from plants growing at different densities and harvested at two development stages did not show significant differences

Table 3. Yield and essential oil content of marjoram plants (mean of 2006 and 2007)
Tabela 3. Plon majeranku i zawartość olejku eterycznego (średnio z 2006 i 2007)

Plant spacing Rozstawa sadzenia (cm)	Harvest time Termin zbioru	Yield of fresh herb Plon świeżego ziela kg m^{-2}	Yield of air dry herb Plon powietrznie suchego ziela kg m^{-2}	Oil content Zawartość olejku %
20×40	I*	0.29	0.06	1.45
	II	0.67	0.13	1.85
Mean – Średnio		0.48	0.10	1.65
30×30	I	0.44	0.11	1.65
	II	0.89	0.23	1.70
Mean – Średnio		0.67	0.17	1.68
30×40	I	0.36	0.09	1.45
	II	0.75	0.21	1.66
Mean – Średnio		0.56	0.15	1.56
40×40	I	0.57	0.09	1.50
	II	0.85	0.26	1.75
Mean – Średnio		0.71	0.18	1.63
Mean harvest time	I	0.42	0.09	1.51
Średnio termin zbioru	II	0.79	0.21	1.74
Mean – Średnio		0.61	0.15	1.63
LSD $NIR_{0.05}$:				
plant spacing – rozstawa sadzenia		0.12	0.03	n.s.
harvest time – termin zbioru		0.19	0.06	0.20
interaction – współdziałanie		0.15	0.02	0.33

*See table 2 – Patrz tabela 2

Table 4. Chemical composition of marjoram herb (mean of 2006 and 2007)
Tabela 4. Skład chemiczny ziela majeranku (średnio z 2006 i 2007)

Plant spacing Rozstawa sadzenia cm	Harvest time Termin zbioru	N-total N-og	$N-NH_4$	$N-NO_3$	P	K	Ca	Mg	$S-SO_4$	Cl
		% d. m. % s. m.								
20×40	I*	3.20	-	0.09	0.29	2.04	0.90	0.06	0.26	0.38
	II	2.84	0.03	0.04	0.19	1.47	0.74	0.07	0.22	0.27
Mean – Średnio		3.02	-	0.06	0.24	1.75	0.82	0.07	0.24	0.33
30×30	I	3.06	-	0.22	0.21	1.75	0.94	0.06	0.21	0.29
	II	3.24	0.08	0.05	0.20	1.80	0.92	0.07	0.22	0.25
Mean – Średnio		3.15	-	0.14	0.21	1.78	0.93	0.07	0.22	0.27
30×40	I	3.05	-	-	0.18	2.04	0.98	0.06	0.23	0.38
	II	2.67	-	0.04	0.22	1.56	1.00	0.08	0.25	0.29
Mean – Średnio		2.86	-	-	0.20	1.80	0.99	0.07	0.25	0.34
40×40	I	3.06	-	-	0.25	2.06	0.79	0.09	0.22	0.37
	II	2.81	-	0.04	0.20	1.70	0.75	0.07	0.19	0.30
Mean – Średnio		2.94	-	-	0.23	1.88	0.77	0.08	0.21	0.34
Mean harvest time	I	3.09	-	0.08	0.23	1.97	0.90	0.07	0.23	0.36
Średnio termin zbioru	II	2.89	0.06	0.04	0.20	1.63	0.85	0.07	0.22	0.28
Mean – Średnio		2.99	-	0.06	0.22	1.80	0.88	0.07	0.23	0.32
LSD $NIR_{0.05}$:										
plant spacing – rozstawa sadzenia		n.s.	-	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
harvest time – termin zbioru		n.s.	-	0.02	n.s.	0.30	n.s.	n.s.	n.s.	n.s.
interaction – współdziałanie		n.s.	-	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

*See table 2 – Patrz tabela 2

Table 5. Essential oil composition of *Origanum majorana* L. in dependence on the harvest time
Tabela 5. Skład olejku eterycznego *Origanum majorana* L. zależnie od terminu zbioru

No.	Compound Związek	RI Indeks retencji	Harvest time – Termin zbioru					
			10.07.06		20.06.07		10.07.07	
			%	±SD	%	±SD	%	±SD
1.	α-thujene	932	1.10	0.01	0.54	0.01	0.58	0.01
2.	α-pinene	939	0.83	0.01	0.63	0.00	0.65	0.02
3.	sabinene	977	8.78	0.03	7.58	0.02	7.90	0.00
4.	β-pinene	983	0.46	0.00	0.32	0.01	0.32	0.01
5.	myrcene	993	2.07	0.02	1.27	0.05	1.11	0.01
6.	p-mentha-1(7),8-diene	1008	-	-	tr.	-	-	-
7.	α-phellandrene	1010	tr.	-	0.10	0.00	0.09	0.01
8.	α-terpinene	1020	5.92	0.03	5.36	0.07	7.11	0.05
9.	p-cymene	1028	-	-	0.07	0.07	0.12	0.02
10.	limonene	1032	1.52	0.01	1.23	0.01	1.18	0.02
11.	β-phellandrene	1034	2.00	0.02	1.75	0.06	1.83	0.02
12.	γ-terpinene	1059	9.21	0.01	8.33	0.05	11.31	0.01
13.	cis-sabinene hydrate	1072	5.27	0.02	5.57	0.06	5.77	0.02
14.	terpinolene	1086	2.20	0.01	1.77	0.02	2.36	0.02
15.	linalool	1100	1.04	0.00	0.66	0.03	0.74	0.01
16.	trans-sabinene hydrate	1102	21.52	0.06	25.42	0.08	14.39	0.09
17.	cis-p-menth-2-en-1-ol	1128	1.19	0.02	1.19	0.00	1.42	0.04
18.	trans-p-menth-2-en-1-ol	1148	0.61	0.00	0.42	0.03	0.52	0.01
19.	borneol	1180	-	-	tr.	-	-	-
20.	terpinen-4-ol	1187	13.69	0.04	15.19	0.01	20.70	0.06
21.	α-terpineol	1203	5.03	0.06	3.38	0.21	3.29	0.07
22.	cis-dihydro carvone	1216	0.15	0.01	0.09	0.00	0.08	0.00
23.	cis-sabinene hydrate acetate	1222	8.07	0.02	0.15	0.09	0.22	0.01
24.	linalyl acetate	1254	2.57	0.08	3.10	0.09	2.63	0.10
25.	trans-sabinene hydrate acetate	1257	-	-	10.21	0.05	10.86	0.08
26.	terpinen-4-ol acetate	1305	-	-	0.33	0.02	0.44	0.00
27.	α-terpinyl acetate	1356	-	-	0.12	0.01	-	-
28.	E-caryophyllene	1430	3.52	0.01	2.90	0.02	2.40	0.00
29.	α-humulene	1470	-	-	0.15	0.02	0.11	0.00
30.	bicyclogermacrene	1511	-	-	2.12	0.01	1.86	0.01

tr. – traces – ilości śladowe

between mean values, except from nitrates (V) and potassium contents in herb from plants harvested at the beginning of flower bud forming and full blooming (tab. 4). Plants grown at higher density contained more total nitrogen and nitrates (V) as compared to other ones. Concentrations of phosphorus, potassium, magnesium, chlorides, and sulfides were similar at plants cultivated with various spacing. The marjoram herb harvested at different development stages contained similar amount of total nitrogen, phosphorus, magnesium, chlorides, and sulfides. Plants harvested at flower bud formation stage accumulated higher levels of nitrates and potassium (0.08 and 1.97% DM) than those at full flowering stage (0.06 vs. 1.63% DM, respectively).

The GC analysis of essential oils from marjoram plants harvested at bud and full flowering stages revealed presence of 30 compounds (tab. 5). Following substances dominated: trans-sabinene hydrate, terpinen-4-ol, trans-sabinene hydrate acetate (unidentified in 2006), sabinene, γ-terpinene, α-terpinene, cis-sabinene hydrate, and cis-sabinene hydrate acetate (2006). Some differences in the amounts of particular oil constituents at plants at various development stages were recorded. Oil from plants forming flower buds contained much more trans-sabinene hydrate (25.42%) than that from fully flowering marjoram herbs (14.39%). Also the percentage of myrcene, linallyl acetate, E-caryophyllene, and bicyclogermacrene was higher. Essential oil produced by plants harvested at full flowering stage was characterized by higher share of sabinene, α-terpinene, γ-terpinene, cis-sabinene hydrate, terpinolene, terpinen-4-ol, and trans-sabinene hydrate acetate than oil from forming flower buds.

DISCUSSION

The marjoram cultivated from a seedling allowed for achieving large fresh and air-dried herb yields, abundant in essential oils and minerals. Studies carried out by Jadczak and Orłowski [1998] indicated that marjoram grown from a seedling – not from a direct sowing – gave better effects. Czarnecki and Załęcki [1986] reported that the direct sowing of marjoram seeds allowed for obtaining much higher herb yield than in the case of seedling, although essential oil content was slightly lower in the former as compared to the other plants. It seems that weather conditions largely affect the marjoram growth. Seidler-Łożykowska [2007] reported that essential oil content in herb of marjoram 'Miraż' cv. depended on average daily temperature and insolation intensity. Considering these data and the changeable weather conditions in recent years, founding marjoram plantations from seedling could be regarded as less fallible from direct sowing. The studied marjoram plants reached mean height of 31.5 cm and diameter of 32.6 cm. Similar values were obtained by Martyniak-Przybyszewska and Wojciechowski [2004] whereas these obtained by Jadczak and Orłowski [1998] and Zawiślak [2008] were much lower. That discrepancy proves a great dependence of marjoram plant growth on weather conditions. Here achieved results indicate that marjoram height more depended on development stage than setting density. The full flowering stage was characterized by larger gains of the mean height than flower bud stage. As Gregorczyk [1997] reports, the maximum marjoram growth rate takes place quite late, and its course is typically sigmoidal: the beginning of elongation growth rate is low, it increases till the flowering beginning with a maximum value, and subsequently decreases. The size of marjoram plant expressed by their diameter, also depended on development stage and plant density. Plants growing in the smallest density had the best conditions to tiller and to flower; the process was intensive till full flowering, which was proved by higher number of stems and branches at plants harvested during flower bud formation. The flowering biology analyses of three Polish sweet marjoram populations performed by Suchorska and Tołwiński [1998] revealed that marjoram created mainly female flowers, and the number of inflorescences on the main shoot equaled 109 to 251. Results achieved in present study are completely consistent with above ones.

The obtained yield values remain considered with those achieved by Seidler-Łożykowska et al. [2008] and Zawiślak [2008]. Yield of marjoram herb significantly depended on plant density and harvest time, which was confirmed by works made by Martyniak-Przybyszewska and Wojciechowski [2003] as well as Zawiślak [2008]. The highest fresh and air-dried yield (respectively 0.71 and 0.18 kg m^{-2}) was achieved from plants grown at the smallest density, which could be explained with more intensive tillering and more abundant flowering of marjoram plants. These results do not confirm those obtained by Martyniak-Przybyszewska and Wojciechowski [2004], who found the opposite dependence.

The chemical composition of harvested marjoram herb partly depended on plant density and harvest time. More total nitrogen and nitrates (V), while less potassium and chlorides was recorded in herb of plants growing at higher density as compared to other ones. Concentrations of these components were comparable to those found by Dzida and Jarosz [2006] as well as Seidler-Łożykowska et al. [2008], except from nitrates and magnesium. Although concentration of the latter in herb of marjoram cultivated in the greenhouse [Dzida and Jarosz 2006], than in here presented study. Studied plants accumulated 1.63% of essential oils in air-dried herb. Marjoram plants growing denser and harvested at full flowering stage appeared to be more abundant in oils than other ones. As it follows from other authors' examinations [Tabanca et al. 2004, Dzida and Jarosz 2006, Seidler-Łożykowska et al. 2008, Zawiślak 2008], the essential oil content in marjoram herb varied depending on the variety, cultivation method, and weather conditions. Seidler-Łożykowska [2007], when analyzing the weather impact on marjoram essential oils, found a positive correlation between the oil content and mean daily temperature as well as insolation, while there were no dependencies between the rainfall level and contents of essential oil. Weather conditions during present experiments, could be considered as favorable, not only for marjoram growth and yielding, but also for the essential oil accumulation.

Composition of sweet marjoram essential oils is abundant and characterized by significant variability. Vera and Chane-Ming [1999] reported that oil of *Origanum majorana* L. grown in tropical climate was a composition of 45 compounds with dominating: terpinen-4-ol (38%) and cis-sabinene hydrate (15%). Zawiślak [2008] identified 35 compounds in marjoram essential oil with the main component – trans-sabinene hydrate. According to Suchorska-Tropiło et al. [2000], linalool dominated in marjoram oil. Tabanca et al. [2004], when comparing the chemical composition of essential oils from *Origanum majorana* L. and *Origanum* × *majoricum* Cambess, reported cis-sabinene hydrate as dominating compound. And similarly, Edris et al. [2003] counted marjoram cultivated in Egypt to cis-sabinene hydrate/terpinene-4-ol chemotype. Vági et al. [2004] reported that terpinene-4-ol was characterized by the highest percentage and cis-sabinene hydrate was found only after super-critical extraction and only at small amounts (1.1%). Novak et al. [2000] found that epimeric monoterpene alcohols (trans-sabinene hydrate, cis-sabinene hydrate, and cis-sabinene hydrate acetate) were the main components of marjoram essential oil.

In present study, composition of the essential oil depended on the harvest time and weather conditions during marjoram vegetation. Oil from plants harvested at the full flowering stage in 2006 contained the most trans-sabinene hydrate (21.52%), while in 2007 terpinen-4-ol (20.70%). Essential oil from marjoram harvested at flower buds stage contained largest amounts of trans-sabinene hydrate (25.42%). When comparing the composition of essential oils from marjoram herb harvested at both development stages, the highest differences in α- and γ-terpinene, trans-sabinene hydtrae, terpinen-4--ol, cis-sabinene acetate, and trans-sabinene hydrate could be observed, which proved these compounds conversions during the plant's development. Zawiślak [2008] also found different contents of trans-sabinene hydrate and terpinen-4-olu in essential oils originating from flowered plants and those re-grown after the first harvest. The results obtained here justify including the studied marjoram into the group of trans-sabinene/terpinen-4-ol.

CONCLUSIONS

1. A significant influence of plant density and herb harvest time on marjoram growth and yield was recorded. At the smallest density were noted the largest fresh and air-dried herb yields.

2. Contents of minerals and nitrates in marjoram herb depended on plant density and harvest time. Herb of plants grown at denser spacing contained more total nitrogen and nitrates (V) as well as less potassium, than those grown at lower density. At full flowering stage, marjoram herb contained significantly less nitrates than at the earlier stage.

3. Herb harvested at full flowering stage was distinguished by significantly higher essential oil content than that collected at bud formation stage. Plants grown at denser spacing produced more oil.

4. Trans-sabinene hydrate and terpinene-4-ol were dominating components of marjoram essential oil. Percentage of particular compounds depended on the development stage of a plant and weather conditions during vegetation.

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WPŁYW GĘSTOŚCI SADZENIA ORAZ TERMINU ZBIORU ROŚLIN NA PLON ORAZ SKŁAD CHEMICZNY MAJERANKU OGRODOWEGO (*Origanum majorana* L.)

Streszczenie. Badania przeprowadzone w latach 2006–2007 dotyczyły oceny wzrostu, plonu i składu chemicznego ziela majeranku w zależności od gęstości sadzenia roślin i terminu zbioru ziela. Zastosowano cztery rozstawy sadzenia roślin: 20 × 40, 30 × 30, 30 × 40 i 40 × 40 cm, ziele majeranku zbierano w okresie tworzenia pąków kwiatowych i w pełni kwitnienia. Najmniejsze zagęszczenie sprzyjało rozkrzewianiu się i kwitnieniu roślin, co wpłynęło wyraźnie na wielkość plonu ziela. Rośliny rosnące w najmniejszym zagęszczeniu (rozstawa 40 × 40 cm) odznaczały się największym plonem świeżego i powietrznie suchego ziela (odpowiednio: 0,71 i 0,18 kg m^{-2}). Ziele roślin rosnących w większym zagęszczeniu zawierało więcej azotu ogółem i azotanów oraz mniej potasu, niż roślin rosnących w mniejszym zagęszczeniu. Zbiór ziela w fazie pełnego kwitnienia okazał się korzystny z uwagi na istotnie mniejszą koncentrację azotanów. Ziele zbierane w fazie pełnego kwitnienia roślin odznaczało się istotnie większą zawartością olejku eterycznego, niż ziele zbierane w fazie tworzenia pąków kwiatowych. Więcej olejku gromadziły też rośliny rosnące w większym zagęszczeniu. Dominującymi składnikami olejku majerankowego okazały się hydrat trans-sabinenu i terpinen-4-ol.

Słowa kluczowe: Origanum majorana, majeranek ogrodowy, plon i skład chemiczny ziela, olejek majerankowy

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