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HYSSOP HERB YIELD AND QUALITY DEPENDING ON HARVEST TERM AND PLANT SPACING

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Abstract. Hyssop (*Hyssopus officinalis* L.) is an oil plant, acts antiseptically and stimulates digestion. It is applied both for curative and culinary purposes. Studies conducted in the years 2006–2008 were aimed at the effect of plant harvest term (mid June – plants in vegetative phase, mid July – beginning of flowering, mid August – full blooming, mid September – after flowering) and plant spacing (30 × 30, 40 × 40, 50 × 50 cm) upon yielding and quantity of hyssop herb. Studies were conducted at one-year plantation established from seedlings. Yield of fresh, dry herb and yield of herb without stems was significantly dependent upon the examined factors. Significantly greater fresh herb yield was obtained from plants after flowering (on average: 2.32 $kg \cdot m^{-2}$), just like the dry yield and yield of herb without stems. In the analysis of the effect of plant spacing upon hyssop yielding, it was revealed that the highest fresh herb yield (on average 1.47 $kg \cdot m^{-2}$) was from plants grown in the spacing of 40 × 40 cm, similarly to yield of the dry herb and yield of herb without stems. No significant effect of plant spacing was found on the contents of dry matter, L-ascorbic acid, chlorophyll, carotenoids, oil, tannins and flavonoids. It was demonstrated, however, that the harvest term significantly effects the contents of L-ascorbic acid, chlorophyll, carotenoids and essential oil in hyssop herb.

Key words: *Hyssopus officinalis* L., oil, vitamin C, chlorophyll, tannins, flavonoids

INTRODUCTION

Hyssop (*Hyssopus officinalis* L.) belongs to the *Lamiaceae* family and is a perennial plant [Wyk and Wink 2008]. In wild state it grows in France, Italy and in the area of former Yugoslavia [Mitić and Dordević 2000]. It occurs on the lowland, plateau, less frequently on a high-mountain belt. It grows the best on lime substratum, on dry and sunny slopes and meadows, as well as under walls [Wolski et al. 2006]. It is cultivated in many regions of Europe. The plantations can be encountered in Bulgaria, Hungary,

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Holland, France and Italy [Mitić and Dordević 2000]. In Poland it is grown in small extent and it sometimes occurs in the wild form [Strzelecka and Kowalski 2000].

Hyssop is reproduced by means of seeds. Growing from seeds sown directly into the field is less labor consuming than from seedlings, but if the plantation is established from seedlings, plants of leveled size are obtained. Besides, producing seedlings is justified in regions with waterlogged, encrusted soils.

Hyssop is used as a food spice and for aromatizing alcoholic beverages [Mitić and Dordević 2000, Strzelecka and Kowalski 2000]. An herbal material is the hyssop herb (*Hyssopi herba*) collected at the beginning of flowering [Strzelecka and Kowalski 2000, Wyk and Wink 2008]. Hyssop herb contains essential oil, flavonoids, tannins and bitter marrubin [Jambor 2006, Kohlmünzer 2007, Wyk and Wink 2008]. According to Kohlmünzer [2007] the herb contains 1% of oil. It is believed that hyssop reveals similar action to sage, but slightly weaker [Jambor 2006, Kohlmünzer 2007]. It acts antiseptically and stimulates the digestion process [Strzelecka and Kowalski 2000]. Woolf [1999] recommends applying the essential oil in the states of nervous exhaustion. Earlier many illnesses were cured with hyssop preparations. In the last decade its importance decreased, it can now be found on the margin of phytotherapy. At present detailed phytochemical studies of hyssop are needed, because there is an enormous inherent potential in this plant [Jambor 2006]. Agrotechniques works of hyssop are conducted in a very narrow scope. An important aspect of herbal production is, besides the raw material yield, also its quality, which is determined in. a. by the contents of active substances, e.g. essential oil. The aim of the studies was the assessment of yield and quality of hyssop herb, depending on harvest term and planting density.

MATERIAL AND METHODS

The studies were conducted in the years 2006–2008 in the Experimental Farm of the Department of Vegetable Growing and Medicinal Plants of the University of Natural Sciences in Lublin (51°14'N 22°34'E). The hyssop seeds came from the firm PNOS Ożarów Mazowiecki. Seedlings were produced in the glasshouse. Seeds were sown at the end of March into seeding boxes filled with peat substratum. The seedlings were then thinned into the pots. In mid May the seedlings were planted into the field in the following spacings: 30 × 30 cm, 40 × 40 cm, 50 × 50 cm. The experiment was established with the use of random blocks method in four replications. The experiment factors were: plant spacing and the herb harvest term. The surface of one plot, depending on planting density was: 1.8 m^2, 3.2 m^2, 5.0 m^2. Studies were conducted on a one-year plantation.

Experiments were established on fawn soil created of loess formations on chalk marles, containing 1.6% of organic substance. The stand under the cultivation was prepared in accordance with the recommendations of cultivation technology. It was fed with mineral fertilizers in the following doses: 50 kg $N \cdot ha^{-1}$, 70 kg $P_2O \cdot ha^{-1}$, 80 kg $K_2O \cdot ha^{-1}$. The phosphorus, potassium and half the dose of nitrogen fertilizer were brought in during field preparation before planting the seedlings. The remaining dose of nitrogen fer-

tilizer was applied as a single plant feeding after the seedlings had established. During vegetation manual weeding and soil loosening were performed.

Before herb harvest on 20 plants the measurements of height and diameter were performed, and the number of main sprouts was determined. Herb harvest was performed in four terms, depending on the developmental phase of the plant: in mid-June (plants in vegetative phase), in mid-July (beginning of plant-flowering), in mid August (full blooming), in mid September (after flowering). The herb was cut on the height of 8 cm over the soil surface. After harvest the fresh herb yield was determined, and then the raw material was dried in the drying room in the temperature of 30°C. After drying the total dry herb yield was determined, and after removing stems and rubbing on sieves of mesh diameter of 4–5 mm – yield of herb without stems. In the fresh herb the dry matter content was determined [PN-90/A-75101/03], as well as the content of chlorophyll and carotenoids, using 80% acetone for extraction, and then performing absorbance measurement on spectrophotometer at wave length λ = 663 nm, λ = 645 nm for chlorophyll and λ = 470 nm for carotenoids. The carotenoid and chlorophyll contents were reported according to Lichtenthaler and Wellburn [1983]. In fresh herb also L-ascorbic acid content was determined with the use of spectrophotometric method according to J. H. Roe with Ewelin's modification [Korenman 1973], as well as essential oil content by three-hour distillation with water vapor [according to Polish Pharmacopoeia VII 2006]. In the dry material the content of essential oil was examined (according to Polish Pharmacopoeia VII 2006; distillation with water vapor; distillation time – three hours), the tannin content with the use of specrophotometric method [according to Polish Pharmacopoeia VII 2006] in conversion to pyrogalol and flavonoid content converted into quercetin – with the use of spectrophotometric method [according to Polish Pharmacopoeia VI 2002].

The obtained results were statistically elaborated with the use of variance analysis or double qualification at the significance level of α = 0.05.

RESULTS AND DISCUSSION

The thermal conditions in the years 2006–2008 were favorable for the growth and development of hyssop plants (tab. 1). Mean air temperatures from May to September were close to the average temperature of many years. The amount of precipitations enhanced vegetation. Lack of precipitation in the 2nd decade of June , 1st and 3rd decade of July 2006 as well as in the 1st decade of June 2008 did not affect the growth of plants, because, as Wolski et al. [2006] report, hyssop is a plant that grows well in dry areas, which is related to its origin. High amount of precipitation, compared to total precipitation from many years, which was reported in August 2006, did not disturb the growth of plants.

On the basis of the performed measurements it was demonstrated that hyssop plants achieved mean height of 40.8 cm and the diameter of 39.2 cm (tab. 2). Plants growing in different spacing did not significantly differ as to their heights. The largest diameter (on average: 45.7 cm) and the number of shoots (on average: 20.6 pcs.·plant^{-1}) were these of plants growing in the largest spacing (50 × 50 cm), but they only significantly differed

Table 1. Air temperature and total precipitation in 2006–2008 years against a background of many-year averages
Tabela 1. Średnie temperatury powietrza oraz sumy opadów w latach 2006–2008 na tle średnich wieloletnich

	Month Miesiąc	2006				2007				2008				1951–2005
		decade – dekada			mean średnio	decade – dekada			mean średnio	decade – dekada			mean średnio	
		I	II	III		I	II	III		I	II	III		
Temperature Temperatura (°C)	V	13.5	14.6	12.8	13.6	9.9	15.1	19.6	14.9	11.3	13.3	13.6	12.7	13.0
	VI	11.6	17.9	21.1	16.9	18.2	20.0	16.2	18.1	18.0	16.4	18.8	17.7	16.4
	VII	21.2	20.8	23.5	21.9	17.1	21.0	19.3	19.1	17.1	18.9	18.9	18.3	17.8
	VIII	18.4	18.3	15.6	17.3	17.9	18.9	18.4	18.4	19.9	20.7	17.3	19.3	17.1
	IX	15.7	15.9	15.6	15.7	13.8	11.8	13.2	12.9	19.3	8.3	10.2	12.6	12.6
					sum – suma				sum – suma				sum – suma	
Precipitation Opady (mm)	V	9.0	18.4	32.1	59.5	13.5	29.9	37.1	80.5	57.1	34.7	9.8	101.6	57.7
	VI	28.4	0.0	9.5	37.9	52.4	25.4	10.0	87.8	0.0	19.6	6.3	25.9	65.7
	VII	0.0	6.8	0.0	6.8	48.8	35.0	3.2	87.0	39.6	19.3	18.2	77.1	83.5
	VIII	73.0	79.7	45.6	198.3	22.3	12.9	2.4	37.6	11.4	7.0	26.6	45.0	68.6
	IX	11.0	0.0	0.0	11.0	119.4	6.8	3.6	129.8	21.6	45.3	35.3	102.2	51.6

Table 2. Morphological characteristics of hyssop plants depending on harvest term and plant spacing (mean of 2006–2008)

Tabela 2. Charakterystyka morfologiczna roślin hyzopu lekarskiego w zależności od terminu zbioru i rozstawy roślin (średnio z lat 2006–2008)

Harvest term Termin zbioru	Plant spacing Rozstawa roślin (cm)	Plant height Wysokość rośliny (cm)	Plant diameter Średnica rośliny (cm)	Number of main shoots (pcs.·plant $^{-1}$) Liczba pędów głównych (szt.·rośl.$^{-1}$)
In vegetative phase W fazie wegetatywnej	30 × 30	24.9	18.9	9.2
	40 × 40	25.2	22.4	10.0
	50 × 50	29.3	27.8	10.3
	mean – średnio	26.5	23.0	9.8
Beginning of flowering Na początku kwitnienia	30 × 30	42.2	32.6	11.6
	40 × 40	37.8	37.1	16.2
	50 × 50	40.0	42.8	16.2
	mean – średnio	40.0	37.5	14.7
Full blooming W pełni kwitnienia	30 × 30	45.2	38.4	17.5
	40 × 40	48.6	48.6	23.3
	50 × 50	49.9	55.5	27.0
	mean – średnio	47.9	47.5	22.6
After flowering Po przekwitnięciu	30 × 30	45.9	39.7	19.4
	40 × 40	49.5	50.4	25.5
	50 × 50	51.1	56.8	29.1
	mean średnio	48.8	49.0	24.7
Mean Średnio	30 × 30	39.5	32.4	14.4
	40 × 40	40.3	39.6	18.7
	50 × 50	42.6	45.7	20.6
	mean – średnio	40.8	39.2	17.9
LSD $NIR_{0.05}$				
harvest term – termin zbioru		6.74	8.56	6.09
plant spacing – rozstawa		n.s.	6.68	4.78
interaction – interakcja		n.s.	n.s.	n.s.

from plants cultivated in the smallest spacing (30 × 30 cm). In the studies a significant effect of harvest term upon plant morphological features was demonstrated. Hyssop plants, harvested in full blooming and after flowering, achieved significantly the largest height, plant diameter and number of main shoots, compared to plants being in the earlier developmental phases. The height of plants in the phase of full blooming was on average : 47.9 cm, slightly more after flowering – on average: 48.8 cm, respectively, for these phases plant diameter was: 47.5 cm and 49.0 cm, whereas the number of main shoots was 22.6 pcs.·plant^{-1} and 24.7 pcs.·plant^{-1}. Studies conducted by Rosłon et al. [2002] revealed that hyssop (*Hyssopus officinalis* L.) plants in full blooming achieved the height of 70 cm. Thus, they were higher than those examined in the experiment. In the observations conducted by Martyniak-Przybyszewska [2005] the height of hyssop plants in August was 51.2 cm on average.

The quantity of fresh, dry herb and herb without stems yield significantly depended upon the examined factors (tab. 3). Significantly the highest yield of fresh herb was obtained from plants that were ceasing to flower (on average: 2.32 $kg \cdot m^{-2}$), similarly to the dry herb yield (on average: 0.84 $kg \cdot m^{-2}$) and herb without stems (on average: 0.42 $kg \cdot m^{-2}$). The plants collected in the earliest period (in the vegetative phase) gave the lowest yields of fresh, dry herb and herb without stems (respectively: 0.30 $kg \cdot m^{-2}$, 0.06 $kg \cdot m^{-2}$, 0.04 $kg \cdot m^{-2}$), but this raw material contained the smallest amount of stems, because the share of herb without stems in dry herb was the highest and it equaled 65.0%. The herb collected from plants being in beginning of flowering also had a high share of herb without stems in dry herb – 61.45%. It is a very significant feature at the assessment of raw material quality, because for the preparation of herbal mixtures the herb with low share of stems is most desired. Literature reports inform that the developmental phase of collected plants significantly effects the yielding. Badi et al. [2004] obtained the highest dry herb yield at the beginning of thyme flowering. In the case of common origanum, the best period for harvesting was full flowering of plants [Nurzyńska-Wierdak 2009].

Table 3. Yield of hyssop plants depending on harvest term and plant spacing (mean of 2006–2008)
Tabela 3. Plon hyzopu lekarskiego w zależności od terminu zbioru i rozstawy roślin (średnio z lat 2006–2008)

Harvest term Termin zbioru	Plant spacing Rozstawa roślin (cm)	Yield of fresh herb Plon świeżego ziela ($kg \cdot m^{-2}$)	Yield of dry herb Plon suchego ziela ($kg \cdot m^{-2}$)	Yield of herb without stems Plon ziela otartego ($kg \cdot m^{-2}$)	Share of herb without stems in dry herb Udział ziela otartego w suchym (%)
In vegetative phase W fazie wegetatywnej	30 × 30	0.21	0.05	0.03	60.00
	40 × 40	0.56	0.10	0.06	60.00
	50 × 50	0.13	0.04	0.03	75.00
	mean – średnio	0.30	0.06	0.04	65.00
Beginning of flowering Na początku kwitnienia	30 × 30	0.42	0.10	0.06	60.00
	40 × 40	0.71	0.17	0.09	52.94
	50 × 50	0.28	0.07	0.05	71.42
	mean – średnio	0.47	0.11	0.07	61.45
Full blooming W pełni kwitnienia	30 × 30	1.26	0.31	0.15	48.39
	40 × 40	1.73	0.46	0.20	43.48
	50 × 50	0.88	0.22	0.08	36.36
	mean – średnio	1.29	0.33	0.14	42.74
After flowering Po przekwitnięciu	30 × 30	2.29	0.69	0.35	50.72
	40 × 40	2.88	1.35	0.67	49.62
	50 × 50	1.79	0.48	0.24	50.00
	mean średnio	2.32	0.84	0.42	50.11
Mean Średnio	30 × 30	1.04	0.29	0.15	51.72
	40 × 40	1.47	0.52	0.25	48.07
	50 × 50	0.77	0.20	0.10	50.00
	mean – średnio	1.09	0.33	0.17	49.93
LSD $NIR_{0.05}$					
harvest term – termin zbioru		0.101	0.121	0.056	
plant spacing – rozstawa		0.079	0.095	0.044	
interaction – interakcja		0.228	0.276	0.128	

Analyzing the effect of plant spacing upon yielding of hyssop, the highest demonstrated yield of fresh herb (on average: 1.47 $kg \cdot m^{-2}$) was from plants grown in the spacing of 40 × 40 cm, whereas the lowest (on average: 0.77 $kg \cdot m^{-2}$) was that of hyssop growing in the largest spacing (50 × 50) (tab. 3). The yield of dry herb and herb without stems was also significantly the highest from plants cultivated in the spacing of 40 × 40 cm and equaled, respectively: 0.52 $kg \cdot m^{-2}$ and 0.25 $kg \cdot m^{-2}$. In the studies by Khazaie et al. [2008] hyssop plant density had no significant effect upon the herb weight .

In the performed experiment it was found that in the raw material from the smallest spacing plants (30 × 30 cm) the share of herb without stems in dry herb was the highest – it equaled 51.72% (tab. 3). In the material obtained from plants grown in larger spacings the share of herb without stems in dry herb ranged from 48.07% (spacing: 40 × 40 cm) to 50.0% (spacing: 50 × 50 cm).

Study works on the relationship between plant spacing and yielding of various herbal plants show that this factor is not always significantly influential. In the studies by Nurzyńska-Wierdak and Dzida [2009] planting density had a significant effect upon yielding of marjoram. A similar dependence was demonstrated by Martyniak-Przybyszewska and Wojciechowski [2003] in their experiments on marjoram and basil. In the studies by Badi et al. [2004] a significant relationship was demonstrated between spacing and yielding of common thyme. In the work by Biesiada and Wołoszczak [2007] no significant effect of plant spacing upon yielding of stinging nettle was reported.

The chemical composition analysis performed in fresh hyssop herb did not reveal any significant dependence between plant spacing and the contents of dry matter, L-ascorbic acid , chlorophyll, carotenoids and essential oil (tab. 4). However, the hyssop herb harvest date significantly effected the content of dry matter. The highest share of dry matter was demonstrated in the herb harvested after flowering (26.43%), and the lowest in the raw material from plants being in vegetative phase (8.74%). Mean dry matter contents in hyssop herb was 17.47%. Slightly lower dry matter content in hyssop herb was found in the studies by Grzeszczuk and Jadczak [2008] – 15.35%. In the fresh raw material of other seasoning plants the dry matter contents were differentiated. The most abundant in dry matter were, according to Martyniak-Przybyszewskiej and Wojciechowski [2004] were: common origanum (25.6%), summer savory (23.9%), marjoram (22.9%), tarragon (21.9%) and thyme (21.0%). In the studies by Dzida [2010] the share of dry matter in sweet basil depended upon the cultivar (25.6–32.0%).

A significant dependence was found between harvest term and the contents of L-ascorbic acid, chlorophyll, carotenoids and essential oil (tab. 4). The most L-ascorbic acid was contained in hyssop herb cut at the beginning of flowering (on average: 31.19 $mg \cdot 100\ g^{-1}$ f.w.), significantly less was found in the raw material obtained from plants collected in the vegetative phase (on average: 17.15 $mg \cdot 100\ g^{-1}$ f.w.) and after flowering (on average: 15.10 $mg \cdot 100\ g^{-1}$ f.w.). Mean content of L-ascorbic acid in hyssop herb was 21.56 $mg \cdot 100\ g^{-1}$ f.w. In the studies by Grzeszczuk and Jadczak [2008] the content of L-ascorbic acid in fresh hyssop herb was three times as high (63.60 $mg \cdot 100\ g^{-1}$ f.w.), after the material had been frozen the content of vitamin C decreased to the level of 22.20 $mg \cdot 100\ g^{-1}$ f.w., and after 6 and 12 months of cold storage further decrease of L-ascorbic acid content was observed in hyssop herb.

Table 4. Content of dry matter, L-ascorbic acid, chlorophyll, carotenoids and essential oil in the fresh herb of hyssop depending on harvest term and plant spacing (mean of 2006–2008)

Tabela 4. Zawartość suchej masy, kwasu L-askorbinowego, chlorofilu, karotenoidów i olejku eterycznego w świeżym zielu hyzopu lekarskiego w zależności od terminu zbioru i rozstawy roślin (średnio z lat 2006–2008)

Harvest term Termin zbioru	Plant spacing Rozstawa roślin (cm)	Dry matter Sucha masa (%)	L-ascorbic acid ($mg \cdot 100\ g^{-1}$ f.m) Kwas L-askorbinowy ($mg \cdot 100\ g^{-1}$ ś.m)	Chlorophyll a ($mg \cdot 100\ g^{-1}$ f.m) Chlorofil a ($mg \cdot 100\ g^{-1}$ ś.m)	Chlorophyll b ($mg \cdot 100\ g^{-1}$ f.m) Chlorofil b ($mg \cdot 100\ g^{-1}$ ś.m)	Chlorophyll a+b ($mg \cdot 100\ g^{-1}$ f.m) Chlorofil a+b ($mg \cdot 100\ g^{-1}$ ś.m)	Carotenoids ($mg \cdot 100\ g^{-1}$ f.m) Karotenoidy ($mg \cdot 100\ g^{-1}$ ś.m)	Essential oil Olejek eteryczny (%)
In vegetative phase W fazie wegetatywnej	30 × 30	7.82	15.32	44.82	13.45	58.27	20.54	0.14
	40 × 40	9.08	18.56	47.34	15.93	63.27	19.78	0.15
	50 × 50	9.32	17.57	44.87	17.90	62.77	24.86	0.17
	mean – średnio	8.74	17.15	45.68	15.76	61.44	21.73	0.15
Beginning of flowering Na początku kwitnienia	30 × 30	14.01	28.72	50.54	22.68	73.22	29.03	0.23
	40 × 40	13.62	31.64	45.62	22.13	67.75	21.05	0.22
	50 × 50	17.79	33.22	47.96	21.55	69.51	23.53	0.22
	mean – średnio	15.14	31.19	48.04	22.12	70.16	24.54	0.22
Full blooming W pełni kwitnienia	30 × 30	19.76	22.38	39.56	22.02	61.58	20.41	0.26
	40 × 40	19.43	24.78	34.73	23.60	58.33	19.99	0.24
	50 × 50	19.51	21.27	41.17	17.65	58.82	17.14	0.25
	mean – średnio	19.57	22.81	38.47	21.09	59.58	19.18	0.25
After flowering Po przekwitnięciu	30 × 30	26.26	13.84	26.71	16.53	43.24	12.28	0.18
	40 × 40	26.40	18.28	26.89	22.65	49.54	17.21	0.20
	50 × 50	26.64	13.17	28.89	17.72	46.61	16.02	0.17
	mean – średnio	26.43	15.10	27.50	18.96	46.46	15.17	0.18
Mean Średnio	30 × 30	16.96	20.06	40.41	18.67	59.08	20.56	0.20
	40 × 40	17.13	23.31	38.64	21.08	59.72	19.51	0.20
	50 × 50	18.31	21.30	40.72	18.70	59.42	20.39	0.20
	mean – średnio	17.47	21.30	39.92	19.48	59.41	20.15	0.20
LSD $NIR_{0.05}$								
harvest term – termin zbioru		5.394	10.426	9.295	6.300	12.179	8.717	0.069
plant spacing – rozstawa		n.s.	n.s.	n.s.	n.s	n.s	n.s.	n.s.
interaction – interakcja		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Analyzing the level of L-ascorbic acid in other seasoning plants, lower contents than in hyssop herb were found in tarragon herb (9.8 mg·100 g^{-1} f.w.), basil (11.9 mg·100 g^{-1} f.w.) and origanum (15.2 mg·100 g^{-1} f.w.), whereas more was contained in thyme herb (18.4 mg·100 g^{-1} f. w.) and marjoram (19.9 mg·100 g^{-1} f.w.) [Martyniak-Przybyszewska and Wojciechowski 2004].

Considering the division of vegetables, fruits and herbs into groups on the basis of vitamin C contents, presented by Nowak [2004], hyssop herb is qualified in the group of raw materials with the lowest content of L-ascorbic acid (below 50 mg·100 g^{-1} f.w.), in which the author also included marjoram.

Table 5. Content of essential oil, flavonoids and tannins in the herb without stems of hyssop depending on harvest term and plant spacing (mean of 2006–2008)

Tabela 5. Zawartość olejku eterycznego, flawonoidów oraz garbników w zielu otartym hyzopu lekarskiego w zależności od terminu zbioru i rozstawy roślin (średnio z lat 2006–2008)

Harvest term Termin zbioru	Plant spacing Rozstawa roślin (cm)	Essential oil Olejek eteryczny (%)	Flavonoids Flawonoidy (%)	Tannins Garbniki (%)
In vegetative phase W fazie wegetatywnej	30 × 30	0.67	0.36	0.43
	40 × 40	0.70	0.43	0.41
	50 × 50	0.63	0.38	0.34
	mean – średnio	0.67	0.39	0.39
Beginning of flowering Na początku kwitnienia	30 × 30	1.07	0.50	0.75
	40 × 40	1.30	0.44	0.48
	50 × 50	1.20	0.54	0.52
	mean – średnio	1.19	0.49	0.58
Full blooming W pełni kwitnienia	30 × 30	1.67	0.42	0.62
	40 × 40	1.77	0.55	0.74
	50 × 50	1.50	0.51	0.57
	mean – średnio	1.65	0.49	0.64
After flowering Po przekwitnięciu	30 × 30	1.03	0.32	0.40
	40 × 40	1.23	0.35	0.47
	50 × 50	1.10	0.44	0.34
	mean – średnio	1.12	0.37	0.40
Mean Średnio	30 × 30	1.11	0.40	0.55
	40 × 40	1.25	0.44	0.52
	50 × 50	1.11	0.46	0.44
	mean – średnio	1.16	0.43	0.50
LSD $NIR_{0.05}$				
harvest term – termin zbioru		0.293	n.s.	n.s.
plant spacing – rozstawa		n.s.	n.s.	n.s.
interaction – interakcja		n.s.	n.s.	n.s.

Hyssop herb, collected from plants that ceased to bloom also had significantly the lowest contents of chlorophyll a+b (on average: 46.46 mg·100 g^{-1} f.w.) and chlorophyll a (on average: 27.50 mg·100 g^{-1} f.w.) (tab. 4). The contents of carotenoids were also the lowest (on average: 15.17 mg·100 g^{-1} f.w.), but it differed significantly only in the case

of the raw material from plants in the beginning of flowering. The highest oil content in fresh raw material was found in the herb collected from plants in full flowering (0.25%) and at the beginning of flowering (0.22%). These values significantly differed statistically from the remaining ones. In the studies by Garg et al. [1999] fresh hyssop herb collected in May contained 0.25% of oil.

The conducted laboratory tests for the rubbed herb demonstrated that the plant spacing has no significant effect upon the essential oil, tannin and flavonoid contents (tab. 5). Khazaie [2008] confirmed that plant spacing does not significantly influence the oil content in the hyssop herb. In the studies by Nurzyńska-Wierdak and Dzida [2009] marjoram plants growing in greater congestion were more abundant in oil. According to Kołodziej [2010] the appropriate plant spacing enhances better use of solar radiation. However, the intensity of light differently affects the oil content in a plant, which is determined by various routes of oil synthesis in particular plant species [Rumińska 1973].

No significant dependence was found in the experiment between harvest term and the contents of flavonoids and tannins in the rubbed herb (tab. 5). Mean flavonoid content in hyssop herb was 0.43%. The contents of tannins in hyssop herb were on average 0.50%. Due to such a small content of this active substance, hyssop herb cannot be regarded as a tannin raw material.

It was revealed in the studies that the essential oil contents in herb without stems were significantly affected by harvest term. The most oil was contained in the herb collected from plants in full blooming – 1.65%, and the lowest level of oil was found in the herb obtained from the plants that were in vegetative phase – 0.67%. Nemeth et al. [2000] demonstrated that the essential oil contents in hyssop significantly changes during plant growing. In the studies by Rosłon et al. [2002] the content of oil in blooming period did not exceed 1%. The content of this substance was on a similar level in the experiment conducted by Garg et al. [1999] – 1.18%, and according to Rey [2004] it ranged from 0.8 to 1.3%. Wolski et al. [2006] reported that the most oil is contained in hyssop flowers and leaves, whereas in the stems there are trace amounts of it.

CONCLUSIONS

1. A significant effect of harvest term upon the yield of hyssop herb was demonstrated. The highest yield was obtained from the plants after flowering, but the essential oil contents in the rubbed herb obtained from these plants was significantly lower than in the raw material from plants in full blooming. That is why it is more advantageous to obtain raw material for oil from plants in full blooming.

2. Plant spacing significantly effected hyssop herb yield. Plants growing in the spacing of 40 × 40 cm had the highest fresh herb, dry herb and herb without stems yield.

3. No significant effect was found of plant spacing upon the contents of dry matter, L-ascorbic acid, chlorophyll, carotenoids, essential oil, tannins and flavonoids.

4. The hyssop raw material collected from plants in vegetative phase and at the beginning of flowering was characterized by the smallest share of stems in dry herb.

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PLON I JAKOŚĆ ZIELA HYZOPU LEKARSKIEGO W ZALEŻNOŚCI OD TERMINU ZBIORU I ROZSTAWY ROŚLIN

Streszczenie. Hyzop lekarski (*Hyssopus officinalis* L.) jest rośliną olejkową, działa antyseptycznie oraz pobudza trawienie. Stosowany jest zarówno w celach leczniczych, jak i kulinarnych. Badania przeprowadzone w latach 2006–2008 miały na celu określenie wpływu terminu zbioru roślin (połowa czerwca – rośliny w fazie wegetatywnej, połowa lipca – początek kwitnienia roślin, połowa sierpnia – pełnia kwitnienia, połowa września – po przekwitnięciu roślin) oraz rozstawy roślin (30 × 30, 40 × 40, 50 × 50 cm) na plonowanie oraz jakość ziela hyzopu. Badania przeprowadzono na plantacji jednorocznej, założonej z rozsady. Wielkość plonu świeżego, suchego oraz otartego ziela była istotnie zależna od badanych czynników. Istotnie większy plon świeżego ziela uzyskano z roślin przekwitających (średnio 2,32 $kg \cdot m^{-2}$), podobnie jak plon suchego ziela i ziela otartego. Analizując wpływ rozstawy roślin na plonowanie hyzopu, wykazano największy plon świeżego ziela (średnio 1,47 $kg \cdot m^{-2}$) z roślin uprawianych w rozstawie 40 × 40 cm, podobnie jak plon suchego i otartego ziela. Nie stwierdzono istotnego wpływu rozstawy roślin na zawartość suchej masy, kwasu L-askorbinowego, chlorofilu, karotenoidów, olejku, garbników i flawonoidów. Wykazano natomiast, iż termin zbioru roślin ma istotny wpływ na zawartość kwasu L-askorbinowego, chlorofilu, karotenoidów, olejku eterycznego w zielu hyzopu.

Słowa kluczowe: *Hyssopus officinalis* L., olejek, witamina C, chlorofil, garbniki, flawonoidy

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