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YIELDING AND QUALITY OF LAVENDER FLOWERS (*Lavandula angustifolia* Mill.) FROM ORGANIC CULTIVATION

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Abstract. In 2008–2010, in the field experiment, the yield and quality of lavender flowers in organic cultivation were tested. The experiment was established in four different locations in Poland. The following features were evaluated: fresh and dried flower yields, seed yield, weight of 1 000 kernels, essential oil content and its composition and microbiological contamination. Lavender flower yield from organic experiments was higher compared with the yield from conventional cultivation. The content of essential oil in organic lavender flowers was lower then that from conventional ones. The content of essential oil and its composition of lavender flowers did not depend on localization. The satisfied yield of lavender seeds was obtained in organic experiments. The investigated lavender raw materials were below the level of standard contamination for raw materials treated with hot water (A) according to European Pharmacopoeia 7.0.

Key words: lavender, organic cultivation, yield, flowers, quality, essential oil

INTRODUCTION

Genus *Lavandula* belongs to Lamiaceae family and it includes about 39 species however, the most important species are lavender (*Lavandula angustifolia* Mill.), lavandin (*Lavandula intermedia* Emeric.) and spike lavender (*Lavandula spica* L.) [Kara and Baydar 2013]. Lavender (*Lavandula angustifolia* Mill.) is perennial and it is cultivated in many European countries. Lavender can successfully grow in Polish climatic conditions, but during winter with no snow cover can suffers from heavy frosts. Lavender flowers (*Lavandulae flos*) are the raw material, which contains the essential oil (3%) and linalool, geraniol, cymene, camphene, pinene, cumarin, as a main oil components, but also contain phenolic acids (12%) flavonoids and tannins [Robu et al. 2011]. Ac-

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cording to Nartowska [2012] lavender flowers contain essential oil and its components: linalyl acetate (40%), linalool (30%), limonene, β-ocymene, 1,8-cineole, camphor, α-terpineol, borneol, but also phenolic acids (rosmarinic acid), ursolic acid, cumarins (umbelliferone, herniarin) flawonoids and sterols. Lavender oil (*Lavandulae aetheroleum*) is known for its antibacterial, antifungal, carminative, antiflatulence, antiholic, sedative and antidepressive activities [Sabara and Kunicka-Styczyńska 2009]. Lavender oil is used in phytotherapy to relief cough, neuralgia, insomnia but also for bath and compress [Ghelardini et al. 1999, Cavanagh and Wilkinson 2002, Hritcu et al. 2012]. Dries flowers are widely used in cosmetic industry as a fragrance ingredient in soaps, perfumes, potpourri due to its aroma and could also be used as an insect repellent. Lavender essential oil is widely used in aromatherapy as a holistic relaxant, antioxidant and antimicrobial agent [Sabara and Kunicka-Styczyńska 2009].

Lavender is native to the Mediterranean and grows in natural sites of lower parts of mountains. Lavender, small shrubby plant, grows 20–60 cm high with irregular, much-branched stems. The leaves are opposite, sessile, lanceolate, linear or lance-shaped and hairy. Flowers are produced in the long spikes on long stems. The spikes consist of rings of 6–10 flowers which are bilabiate, small, 0,8 cm-long with blue, tubular and ribbed calyx and violet-blue corolla. The majority of the oil, extracted from the flowers, is contained in the glands on the calyx [Raev et al. 1996].

The introduction of lavender into organic cultivation will help to obtain high quality raw material, as well as an increase in diversity of crop rotation which is very important on the organic farm [Seidler-Łożykowska et al. 2009]. Organic flowers of lavender can also be used in cosmetic industry. Nowadays, the raw material should fulfill the growing demands of herbal and cosmetic industries about its quality esp.: active substance content, sufficient yield, free of pesticides and heavy metals and microbiologically clean. Therefore, more often organic origin of raw material is welcome. The idea of the experiment was evaluation and comparison the value of lavender flowers from two systems of cultivation: organic and conventional. The main aims of the experiment were testing organic cultivation of lavender, evaluation of its flower yield and quality and possibility of obtaining organic seeds.

MATERIAL AND METHODS

The experiment was carried out in four certified organic farms located in: Jary (N51°17’, E16°52’), Paszków (N50°36’, E16°52’), Plewiska (N52°21’, E16°48’), Słońsk (N52°33’, E14°48’).

In spring 2008, before starting experiment, soil samples were collected from each experimental field to determine the content of macro- and microelements (tab. 1). The collected samples were analyzed by the universal method [Kozik and Golcz 2011]. Extraction of P, K, Mg was carried out using 0.03 M of CH_3COOH with a quantitative proportion of 1: 10 (soil: extraction solution). After extraction, the following determinations were made: P – colorimetrically with *ammonium vanadomolybdate* method [Nowosielski 1988]; K – photometrically [Nowosielski 1988]; Mg – by atomic absorption spectrometry (AAS, Carl Zeiss-Jena apparatus, Germany).

Table 1. Content of macro- and microelements [$mg \cdot dm^{-3}$] in the soil samples in 2008

Location	P	K	Mg	B	Mn	Cu	Zn	Fe	pH
Plewiska ORG	35.5	16.7	2.8	1.03	97	2.7	7.4	561	6.9
Plewiska CONV	16.9	11.1	4.2	0.67	96	2.0	7.9	553	5.0
Paszków ORG	2.0	10.6	8.9	1.15	136	4.0	10.8	1687	5.0
Paszków CONV	6.1	6.4	4.4	0.81	73	1.5	4.3	535	4.3
Słońsk ORG	38.5	24.8	11.7	4.13	166	3.6	15.3	3258	7.2
Jary ORG	14.7	14.0	4.5	0.70	73	2.0	7.7	579	4.7

Microelements (B, Fe, Mn, Zn and Cu) were extracted from soil with Lindsay's solution containing in 1 dm^3: 5 g EDTA (*ethylenediaminetetraacetic acid*); 9 cm^3 of 25% NH_4 solution, 4 g *citric acid* and 2 g $Ca(CH_3COO)_2 \cdot 2H_2O$. Microelements were determined using AAS method [Kabata-Pendias and Pendias 1999]. Soil acidity was determined potentiometrically (soil: water = 1: 2).

In April, 2008 the experiments were established in the randomized complete block design in three repetitions. Each plot had 10 m^2. Lavender population was examined for its usefulness for organic cultivation. Seeds, originated from Botanical Garden of the Institute of Natural Fibres and Medicinal Plants, were sown in greenhouse to produce plantlets which were planted on the field. As a control two experiments in Paszków and Plewiska were established on the conventional fields. In the second and third year, at the full flowering period, the raw material was collected by hand, from the area of 1.0 m^2 of each plot. The flowers were dried in natural conditions, in a shaded and well ventilated place.

The following traits were estimated: yield of fresh and dried flowers, seed yield, weight of 1000 kernels, essential oil content and its composition and the microbiological contamination of dried flowers.

The essential oil was hydrodistillated from flowers with Dering's apparatus following the methods recommended by European Pharmacopoeia 7.0 [2010].

Distillation and GC data: 20.0 g of herbal drugs was placed in 1000 ml round-bottomed flask. Then added 500 ml of *water R*, as a distillation liquid and 0.5 ml of *xylene R*. Distillation was carried out at a rate of 2–3 $ml \cdot min^{-1}$ for 2 hours. The hexane solution of the oil was analyzed by gas chromatography using Perkin Elmer Clarus 500 system. Chromatographic column (Elite – FFAP 30 m) was used in temperature starting at 60°C (1 min), increased by 5°C/min to 230°C. The flow rate of carrier gas (helium) was set at 2.0 ml/min Split-splitless injector was used with the split ratio 1:100 mode at 200°C. Volume of injected sample was 0.2 μl. FID detector was operated at 230°C. The components of test solution, namely *linalool* (Fluka) and *camphore* (Fluka), *geraniol* (Aldrich), *ocymene* (Aldrich), *β-pinene* (Fluka), *myrcene* (Fluka), were located using retentions times from the reference solutions chromatograms. Quantification was made using the normalization procedure.

The evaluation of raw material microbiological contamination was carried out following European Pharmacopoeia 7.0 [2010] standards for raw materials treated with hot water (A) and do not treated with hot water (B). Number of aerobic bacteria, number of yeasts and moulds and number of *Escherichia coli* and *Salmonella* were estimated in dried flowers. Additionally the number of intestine bacteria from family *Enterobacteriaceae* was evaluated. Investigations were done after harvest and 6 months of flowers storage in darkness and room temperature.

Statistical analysis: The normality of distribution of studied traits was tested using Shapiro-Wilk's *W* test ($P < 0.05$) [Shapiro and Wilk 1965]. A two-way analysis of variance (ANOVA) was used to analyze yield of fresh and dried flowers, seed yield, weight of 1000 kernels with year and location as the two fixed factors. A one-way ANOVA was used to examined essential oil content with location as the factor. The mean value and coefficient of variation [Kozak et al. 2010] were calculated. The least significant differences (LSDs) *post hoc* test was used to distinguish significant treatments. The relationships between yield of fresh and dried flowers, seed yield, weight of 1000 kernels were estimated using Pearson correlation coefficients [Kozak et al. 2013]. Analysis of the data was performed using the statistical package GenStat v. 10.1 [GenStat 2007].

RESULTS AND DISCUSSION

The soil from Paszków control and Jary had the lowest acidity 4.3, 4.7 respectively, while the optimum pH was in Plewiska organic and Słońsk (6.9 and 7.2) (tab. 1). The soils from organic fields was richer in most macroelements compared with the soils from conventional fields from the same location (Paszków and Plewiska). The richest soil originated from Słońsk organic field. The content of microelements in the tested soils was from 0.67–4.13 mg B·dm^{-3}, 73–166 mg Mn·dm^{-3}, 1,5 mg Cu·dm^{-3}, 4.3–15.3 mg Zn·dm^{-3}, 535–3258 mg Fe·dm^{-3}. The level of microelements was adequate for most of crops in all soils except content of cooper which was low (tab. 1).

In table 2 the crop rotation on the experimental fields was presented in 2005–2008. In Słońsk and Plewiska the preceding crops were the most suitable by providing organic matter and supplying nitrogen.

Table 2. Crop rotation on the experimental fields 2005–2008

Year	Słońsk	Plewiska	Jary	Paszków
2005	barley	phacelia	corn	white mustard
2006	oat + undersown hairy vetch	cattle manure field pea	triticale	spring barley + undersown clover
2007	cattle manure vegetable	buckwheat	cattle manure potato	clover
2008	experiments			

Analysis of variance indicated that the main effects of year, location as well as year × location interaction were significant for yield of fresh and dried flowers, seed yield, weight of 1000 kernels (tab. 3).

Table 3. Mean squares from two-way analysis of variance for quantitative traits of lavender (2008–2010)

Source of variation	d.f.	Fresh flower yield	Dried flower yield	Seed yield	Weight of 1000 kernels
Year	1	5650.0***	1406.25***	173.36***	0.175***
Location	5	3682.7***	629.16***	184.15***	0.047***
Year × location	5	88.17.5***	878.98***	179.39***	0.035**
Residual	24	106.1	22.28	8.44	0.007

** P < 0.01; *** P < 0.001
d.f. – degrees of freedom

Very little research has been conducted in regard to lavender cultivation. Agronomic studies have been mainly done on the mechanized cultivation and effect of irrigation [Nedkov and Slavov 1990] or nitrogen doses and plant density [Ceylan et al. 1996] in the conventional lavender cultivation.

Table 4. Mean value and coefficient of variation (cv) for lavender flower and seed yield (2008–2010)

Location	Traits									
	Fresh flower yield ($g \cdot m^{-2}$)		Dried flower yield ($g \cdot m^{-2}$)		Essential oil content (%)		Seed yield ($g \cdot m^{-2}$)		Weight of 1000 kernels (g)	
	mean	cv	mean	cv	mean	cv	mean	cv	mean	cv
Plewiska ORG	73.33b	18.63	22.83b	17.17	1.91	1.86	13.45a	69.85	0.75ab	17.51
Plewiska CONV	70.00b	52.29	20.00b	41.23	2.04	18.42	12.95a	83.18	0.64cd	16.85
Paszków ORG	69.17b	72.68	24.33b	26.46	1.78	18.27	6.25b	81.41	0.71bc	13.52
Paszków CONV	27.67d	50.53	7.83d	53.20	1.87	2.65	0.80c	154.92	0.61cd	18.46
Słołsk ORG	102.00a	73.02	38.00a	85.44	1.78	8.37	12.43a	35.03	0.83a	9.48
Jary ORG	51.00c	50.37	14.17c	59.46	1.88	22.57	3.02bc	65.48	0.60d	36.16
Mean	65.5		21.2		1.88		8.15		0.69	
$LSD_{0.05}$	12.27		5.62		0.67		3.46		0.101	

Means followed by the same letters are not significantly different

The average yield of fresh lavender flowers varied from 27.67 (Paszków control) to 102.00 $g \cdot m^{-2}$ (Słońsk) and similar the average yield of dried flowers was from 7.83 (Paszków control) to 38.00 $g \cdot m^{-2}$ (Słońsk) and both yields were significantly different (tab. 4). In both locations (Plewiska and Paszków) the yield of organic fresh and dried flowers was higher than that from conventional cultivation, but only in Paszków the differences were significant. According to Dachler and Pelzmann [1999] the yield of dried lavender flowers estimated from 400–1000 kg·ha^{-1} (40–100 g·m^{-2}), while Kucharski [2010] indicated the dried yield of lavender flower on 300–500 kg·ha^{-1} (30–50 g·m^{-2}). Although yields given by Dachler and Pelzmann [1999] regarding 60 000 plants·ha^{-1}, while Kucharski [2010] only 42 000 plants·ha^{-1}. Yields of dried lavender flowers obtained in our experiments were lower in both organic and conventional cultivation compare with citations. Only yields obtained in Słońsk (organic experiment) were comparable.

The average lavender seed yield was from 0.8 (Paszków control) to 13.45 g·m^{-2} (Plewiska organic) and the biggest seeds (weight of 1000 kernels) were obtained organically in Słońsk (0.83 g) while the smallest were organic from Jary (0.60 g) (tab. 4). In both location the organic seed yield and weight of 1 000 kernels were higher compared with conventional seeds.

The positive correlation was found between fresh and dried herb yield, fresh herb yield and seed yield, dried herb yield and seed yield. The weight of 1000 kernel was not significantly correlated with none of the analyzed traits (tab. 5).

Table 5. The correlation matrix for the quantitative traits of lavender

Trait	Fresh flower yield	Dried flower yield	Seed yield
Fresh flower yield	1		
Dried flower yield	0.910***	1	
Seed yield	0.576***	0.434**	1
Weight of 1000 kernels	-0.028	0.072	0.092

** P < 0.01; *** P < 0.001

Essential oil content of the dried flowers ranged from 1.78 (Paszków organic, Słońsk) to 2.04% (Plewiska control) (tab. 6). Lavender flowers obtained from the conventional cultivation (control) had more essential oil that organic flowers, although it was no significant differences (P > 0.05). These results are similar to those given by Dachler and Peltzman [1999]: 1.5–2.0% of essential oil in lavender flowers. While, high content of essential oil (2.8% cv. ‘Lady’ – 5.0% cv. ‘Grey Lady’) was reported by Renaud et al. [2001] who evaluated six lavender cultivars organically cultivated. The investigation done by Kara and Baydar [2013], who compared four cultivars of lavender, showed that content of essential oil was oscillated from 0.35 to 2.0%. While Zheljazkov et al. [2012] reported lower content of essential oil 0.71–1.30% in the dried lavender flowers.

The main component of essential oil obtained from lavender flowers was linalool which reached from 42.64 (Paszków organic) to 60.02% (Plewiska control) (tab. 6). Content of geraniol oscillated from 7.78 (Paszków control) to 18.36% (Paszków organic) and content of camphor – 0.21 (Paszków control) to 4.10% (Plewiska organic). Content of ocymene varied from 1.64 (Słońsk) to 2.47% (Plewiska organic) and content of β-pinene was from 0.99 (Paszków organic) to 1.51% (Jary). Another detected com-

Table 6. Mean values and coefficients of variation (cv) for lavender essential oil content and its composition (2008–2010)

Trait [%]		Location						$LSD_{0.05}$
		Jary ORG	Paszków ORG	Paszków CONV	Plewiska ORG	Plewiska CONV	Słońsk ORG	
Ess. oil	mean	1.88	1.78	1.87	1.91	2.04	1.78	0.67
	cv*	22.57	18.27	2.65	1.86	18.42	8.37	
Linalool	mean	56.89	42.64	58.74	57.70	60.02	59.49	19.55
	cv	22.63	12.67	14.42	8.86	14.27	6.87	
Geraniol	mean	9.23	18.36	7.78	9.77	9.62	8.91	31.68
	cv	104.8	123.9	99.6	111	108.4	117.1	
Camphor	mean	3.36	3.19	0.21	4.10	3.76	0.93	9.48
	cv	127.1	109.9	17.2	138.3	135	138.3	
β-pinene	mean	1.51	0.99	1.45	1.21	1.26	1.43	3.87
	cv	124.6	111.3	127.8	120.4	103.3	121.6	
Ocymene	mean	2.18	2.24	1.94	2.47	1.76	1.64	2.81
	cv	72.01	73.28	29.89	22.66	61.07	62.09	
Myrcene	mean	1.19	0.82	1.30	1.16	0.95	1.35	0.83
	cv	5.37	25.87	27.2	24.38	9.73	48.89	
Other	mean	23.78	29.27	25.39	21.15	21.41	21.49	67.57
	cv	125.4	117.9	88.3	129.4	121.1	111.3	

*cv – coefficient of variation

pounds was myrcene which was from 0.82 (Paszków organic) to 1.35% (Słońsk). Only six active compounds identified in essential oil of all organic and conventional lavender flowers contributed from 70.73 to 78.85% of the GC profile. In both locations, Paszków and Plewiska the content of geraniol, camphor and ocymene was higher in organic lavender flowers, while the content of linalool and β-pinene was higher in conventional raw material of lavender. The positive correlation of the following compounds was found: linalool and β-pinene, geraniol and camphor and β-pinene, camphor and β-pinene. While negatively was correlated ocymene with linalool, geraniol and β-pinene (tab. 7).

In experiment done by Śmigielski et al. [2013], 47 compounds were detected in lavender essential oil and a dominant share had linalool (24.6%), linalyl acetate (18.0%) and borneol (6.3%). The similar results of lavender oil composition was reported by Khitam Jawad Hamad et al. [2013] who analyzed the wild grown genotypes in Iraq. GC-MS analysis revealed 34 compounds in lavender flowers and major components were: linalool (24.6%), camphor (13.6%), linalyl acetate (8.9%), ocymene (7.6%), 1.8-cineole (7.1%) and borneol (6.4%). Different composition of lavender essential oil was obtained by Kara and Baydar [2013] who analyzed lavender cultivars cultivated in Turkey. GC-MS analysis resulted in the identification of 28 compounds and major compounds were: linalool (28.5–43.9%), linalyl acetate (5.4–25.7%), camphor (6.9–14.3%).

Also Soodabeh Saeidnia et al. [2013], who evaluated aroma profile of lavender cultivated in Teheran, reported that the main compounds of lavender oil was linalool (31.0%), linalyl acetate (18.2%) and lavadulyl acetate (10.7%). None of the presented literature did not analyzed content of essential oil and its compounds in lavender flowers obtained from organic cultivation.

Table 7. The correlation matrix for the lavender essential oil content and its composition (2008–2010)

Trait	Ess. oil	Linalool	Geraniol	Camphor	β-pinene	Ocymene	Myrcene	Other
Ess. oil	1							
Linalool	-0.097	1						
Geraniol	-0.454	0.260	1					
Camphor	-0.087	0.411	0.737**	1				
β-pinene	-0.364	0.725**	0.739**	0.648*	1			
Ocymene	0.427	-0.617*	-0.675*	-0.407	-0.718**	1		
Myrcene	-0.208	0.511	0.032	-0.059	0.559	-0.171	1	
Other	0.362	-0.716**	-0.848***	-0.776**	-0.945***	0.761**	-0.370	1

* $P < 0.05$; ** $P < 0.001$; *** $P < 0.001$

Table 8. Microbiological contamination of lavender flowers after harvest and 6 months of storage (2009–2010)

Location	Aerobic bacteria in 1 g		Yeasts and moulds in 1 g		*Enterobacteriaceae* in 1 g		*Escherichia coli* in 1 g	*Salmonella* in 10 g
	after harvest	after 6 month	after harvest	after 6 month	after harvest	after 6 month		
Plewiska ORG	5 000	1 200	50	40	3 250	130	–	–
Plewiska CONV	1 000	400	55	30	100	60	–	–
Paszków ORG	15 000	2 000	120	–	**9 650**	**4 000**	–	–
Paszków CONV	7 000	1 900	220	100	130	80	–	–
Słońsk ORG	**39 500**	**16 000**	200	90	1 700	950	–	–
Jary ORG	2 000	500	**800**	**100**	550	–	–	–
Standard A	10.000.000		100.000		–		100	–
Standard B	100.000		10.000		1000		absent	absent

The analysis of microbiological purity of the dried lavender flowers after harvest, then after 6 months of storage showed a great diversification of microbiological contamination of raw material, depending on flower origin (tab. 8). The most contaminated by aerobic bacteria were the flowers from Słońsk and the lowest one – from Plewiska control. While the highest amount of yeasts and moulds were noted on lavender flowers from Jary and the flowers from Plewiska (both organic and control) were less contaminated. The contamination of *Enterobacteriaceae* in the flowers from Paszków organic was the highest. Though, all of the investigated lavender raw materials were below the level of standard contamination A (raw materials treated with hot water). While, *Enterobacteriaceae* contamination of lavender flowers from organic experiments of Plewiska, Paszków and Słońsk was exceeded according to standard B (raw material not treated with hot water) [European Pharmacopoeia 2010]. Soil and organic fertilization are the main sources of microbiological contamination of raw material [Kędzia 1999]. After 6 months of storage the microbiological contamination of lavender flowers was diminished in the different rates. According to Kędzia [1999] there are two main reasons of this process: 1. bacteria have different susceptibility for dryness and 2. plant active substances (esp. essential oil, anthocyanins and tannins) have strong effect on raw material microbes. Contamination of raw material organically produced should be controlled, especially for *Escherichia coli* and *Enterobacteriaceae* content, following the fact that organic manure is a basic type of fertilization.

CONCLUSIONS

1. Lavender flower yield from organic experiments was higher compared with the yield from conventional cultivation.
2. The content of essential oil in organic lavender flowers was lower then that from conventional ones.
3. The content of essential oil and its composition of lavender flowers did not depend on localization.
4. The satisfied yield of lavender seeds was obtained in organic experiments.
5. The investigated lavender raw materials were below the level of standard contamination for raw materials treated with hot water (A) according to European Pharmacopoeia 7.

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PLONOWANIE I JAKOŚĆ KWIATÓW LAWENDY WĄSKOLISTNEJ (*Lavandula angustifolia* Mill.) W UPRAWIE EKOLOGICZNEJ

Streszczenie. W latach 2008–2010 oceniano plonowanie i jakość kwiatów lawendy wąskolistnej w ekologicznych doświadczeniach polowych. Doświadczenia zostały założone w czterech certyfikowanych gospodarstwach ekologicznych w różnych częściach Polski. W doświadczeniach oceniano następujące cechy: świeżą i suchą masę surowca, plon nasion, masę 1000 nasion, zawartość olejku eterycznego w suchym surowcu oraz jego skład i poziom zanieczyszczeń mikrobiologicznych surowca. Plon kwiatów lawendy z doświadczeń ekologicznych był większy w porównaniu z uprawą konwencjonalną, natomiast zawartość olejku eterycznego w kwiatach ekologicznych była mniejsza niż w tych pochodzących z doświadczeń konwencjonalnych. Zawartość olejku eterycznego oraz jego skład nie były zależne od systemu uprawy. W doświadczeniach ekologicznych uzyskano satysfakcjonujący plon nasion. Badany surowiec lawendy spełniał wymogi zanieczyszczeń mikrobiologicznych surowców poddawanych działaniu gorącej wody (A) zgodnie z Farmakopeą Europejską 7.0.

Słowa kluczowe: lawenda, uprawa ekologiczna, plon, kwiaty, jakość, olejek eteryczny

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