ISSN 1644-0692
www.acta.media.pl

ACTA Acta Sci. Pol. Hortorum Cultus, 14(5) 2015, 55-67

EFFECT OF ORGANIC CULTIVATION ON YIELD AND QUALITY OF LEMON BALM HERB (*Melissa officinalis* L.)

Katarzyna Seidler-Łożykowska[1], Romuald Mordalski[1], Wojciech Kucharski[1], Elżbieta Kędzia[1], Kamila Nowosad[2], Jan Bocianowski[3]

[1]Institute of Natural Fibres and Medicinal Plants, Poznań

[2]Wrocław University of Environmental and Life Sciences

[3]Poznań University of Life Science

Abstract. The raw material of medicinal plants should fulfill the growing demands of herbal and cosmetic industries about its quality esp.: active substance content, sufficient yield, lack of pesticides and heavy metals residues and microbiologically clean. Therefore, more often organic origin of herbal raw material is welcome. The main aim of the experiment was evaluation and comparison the value of lemon balm herb from organic and conventional cultivation. In 2008–2010, in the field experiment, the yield and quality of lemon balm herb in organic cultivation were tested. The experiment was established in four different locations in Poland. The following features were evaluated: fresh and dried herb yields, seed yield, weight of 1000 seeds, essential oil content and its composition and microbiological contamination. Lemon balm herb yield from organic experiments was lower compared with the yield from conventional cultivation. The content of essential oil in both organic and conventional herbs were similar. The content of essential oil and its composition of lemon balm herb did not depend on localization. The content of two, main oil compounds: neral and geranial was higher in the conventional herbs. The satisfied yield of lemon balm seeds was obtained in organic experiments. The investigated lemon balm 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: lemon balm, cultivation systems, crop, raw material, essential oil

---

Corresponding author: Katarzyna Seidler-Łożykowska, Institute of Natural Fibres and Medicinal Plants, 60-630 Poznań, Wojska Polskiego 71B, e-mail: katarzyna.lozykowska@iwnirz.pl

INTRODUCTION

Lemon balm (*Melissa officinalis* L.) is a valuable medicinal plant native to southern Europe (Mediterranean) and western Asia. It is commonly cultivated in Poland on an area of 5000 ha. Lemon balm herb (*Melissa herba*) and lemon balm leaves (*Melissa folium*), the components of herbal mixtures, are used as a digestive, antispasmodic and antiviral remedy. Lemon balm is also recommended in sleep disturbances and functional gastrointestinal disorders [Aziz and El-Ashry 2009]. Lemon balm essential oil (*Melissa oleum*), obtained from leaves by hydro-distillation, consists mainly of citronellal (2–40%) and citral (10–30%) which is a mixture of two monoterpenes: geranial and neral [Aziz and El-Ashry 2009]. Citral is widely used in food and cosmetic industry due to its lemon aroma. Lemon balm could also be used as an insect repellent [Abbaszadeh et al. 2009].

Lemon balm is a perennial plant that reaches a height of 1 m with hairy, deeply veined, heart-shaped leaves which are 2–8 cm long. Flowers are white or pale pink in small clusters. Lemon balm is a cross-pollinating species and its ovate seeds are black or dark brown. The weight of thousand seeds oscillates from 0.5 to 0.7 g. Lemon balm has a hairy root system with many lateral roots which better adapt to different environmental conditions [Moradkhani et al. 2010]. Lemon balm is susceptible to frost, especially when there is no snow cover. New shoots start to appear early in spring, so they can also suffer from spring frosts.

The introduction of lemon balm 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 herb of lemon balm can also be used in the 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 residues and microbiologically clean. Therefore, more often organic origin of raw material is welcome. Some authors claim that raw material of organic plants contain considerably more bioactive compounds then the conventional ones. In addition organic medicinal plants contain more dry matter which affects the higher productive efficiency [Kazimierczak et al. 2014]. Agrochemicals, used in the conventional production, cause quicker biomass growth resulting in a higher yield, but at the same time in lower concentration of active substances [Herms and Mattson 1992, Brandt and Molgaard 2001].

The idea of the experiment was evaluation and comparison the value of lemon balm herb from two systems of cultivation: organic and conventional. The main aims of the experiment were testing organic cultivation of lemon balm, evaluation of its herb 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 the spring 2008, before starting experiment, soil samples were collected from each experimental field to determine the content of macro- and microelements. 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).

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. Strain 33/II, obtained from Institute of natural Fibers & Medicinal Plants lemon balm breeding program, was examined for its usefulness for organic cultivation. Seeds were sown in the 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. The organic experiments did not include the use of chemical fertilization and pesticides, while in the conventional ones the chemical fertilizers were applied as per recommendation. 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 herb was dried in natural conditions, in a shaded and well ventilated place.

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

The essential oil was hydro-distillated from herbs with Dering's apparatus following the methods recommended by European Pharmacopoeia 7.0 [2010].

The data regarding the soil fertility and crop rotation of experimental sites were given by Seidler-Łożykowska et al. [2014].

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. 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 (3 min), increased by 3°C/min to 200°C. The flow rate of carrier gas (helium) was set at 0.5 ml/min. Split-splitless injector was used with the split ratio 1 : 100 mode at 200°C. Volume of injected sample was 0.1 µl. FID detector was operated at 200°C. The components of test solution, namely *linalool* (Fluka) and *citronellol* (Sigma Aldrich), *geranial* (Sigma Aldrich), *caryophyllene* (Sigma Aldrich), *neral* (Fluka), *geraniol* (Sigma Aldrich), *citronellal* (Sigma Aldrich), 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 herbs. Additionally, the number of intestine bacteria from family *Enterobacteriaceae* was evaluated. Investigations were done after harvest and 6 months of herb 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]. The parallel coordinate plot is proposed as an efficient tool for visualization of 13 traits of lemon balm herb in six locations. Parallel coordinates are a two-dimensional technique for visualization of multidimensional data sets and are an efficient tool for visualizing multivariate data [Bocianowski et al. 2015]. The y-axes are parallel, have the same length, and start with a minimum of the corresponding trait and end with its maximum. Note thus that when a particular location is placed in the middle of a y-axis, it does not mean that its value is around the mean of the corresponding trait – it is the middle point within the trait's range. For a particular location, the points on the adjacent y-axes are joined by a line, thereby picturing a multidimensional characterization of the location. Since many variants of magnesium application are plotted on the same PCP, a particular location's performance can be seen against a background of the whole pool of locations studied. A possibility of graphic distribution of the studied locations described by observed traits was obtained with the use of the canonical varieties analysis plot. Analysis of the data was performed using the GenStat v. 17 statistical package [VSN International 2014].

RESULTS AND DISCUSSION

Results of 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 herbs. The main effects of location and year × location were also significant for seed yield and weight of 1000 seeds, while both traits were no affected by year (tab. 1).

The average yield of fresh lemon balm herb varied from 449.0 (Paszków organic) to 2416.0 $g \cdot m^{-2}$ (Słońsk organic) and similarly the average yield of dried herb was from 93.4 (Paszków organic) to 551.4 $g \cdot m^{-2}$ (Słońsk organic) and both yields were significantly different (fig. 1 and tab. 2). In both locations (Plewiska and Paszków) the yield of conventional fresh and dried herbs was higher than that from organic cultivation, and in the both location the differences were significant. There are not too many research con-

Table 1. Mean squares from two-way analysis of variance for quantitative traits of lemon balm (2008–2010)

Source of variation	d.f.	Fresh herb yield	Dried herb yield	Seed yield	Weight of 1000 seeds
Year	1	4553488***	121177***	252.7	0.0012
Location	5	4742680***	261413***	26073.2***	0.0251***
Year × location	5	740730***	53630***	3120.7*	0.0077**
Residual	22	124054	4235	715.2	0.0008

* – P < 0.05; ** – P < 0.01; *** – P < 0.001
d.f. – degrees of freedom

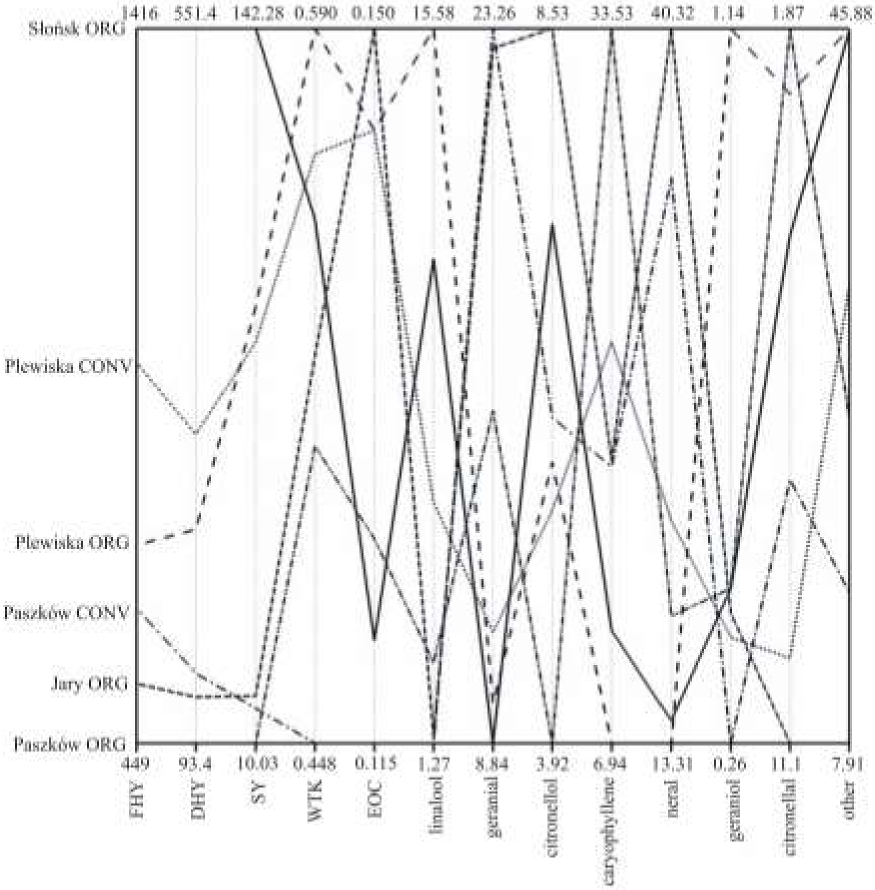

Fig. 1. Parallel coordinate plot of six locations (Słońsk ORG ——; Plewiska CONV ·····; Plewiska ORG – – –; Paszków CONV –·–·–; Jary ORG - - -; Paszków ORG –··–··–) and 13 traits (FHY – fresh herb yield, DHY – dried herb yield, SY – seed yield, WTK – weight of 1000 kernels, EOC – essential oil content)

cerning organic cultivation of lemon balm. According to Dachler and Pelzmann [1999] the yield of fresh lemon balm herb oscillated from 70–300 dt·ha^{-1} (700–3000 g·m^{-2}), and yield of dried herb is from 40–60 dt·ha^{-1} (400–600 g·m^{-2}). They also indicated the yield of lemon balm dried leaves from 15–30 dt·ha^{-1}. While Król [2010] reported the yield of dried lemon balm herb on 30–50 dt·ha^{-1} (300–500 g·m^{-2}). Although yields given by Dachler and Pelzmann [1999] regarding 60 000 plants·ha^{-1}, while Król [2010] 85 000–125 000 plants·ha^{-1} depends on the row space. Yields of lemon balm herb obtained in our experiments were comparable in both organic and conventional cultivation compare with citations. The herb yields obtained in Słońsk (organic experiment) were higher. Reneau [2003] has observed the increase of organic lemon balm herb yield when the plants were mulched with composted horse manure.

Table 2. Mean value and coefficient of variation (cv) for lemon balm herb and seed yield (2008–2010)

Location	Traits									
	fresh herb yield (g·m^{-2})		dried herb yield (g·m^{-2})		essential oil content (ml·100 g^{-1} sm.)		seed yield (g·m^{-2})		weight of 1000 seeds (g)	
	mean	cv	mean	cv	mean	cv	mean	cv	mean	cv
Plewiska ORG	994.0c	42.19	230.2b	26.12	0.145a	43.89	90.83b	9.11	0.590a	1.52
Plewiska CONV	1 496.0b	72.89	291.3b	47.14	0.145a	43.89	84.22b	44.33	0.565ab	9.28
Paszków ORG	449.0e	40.63	93.4c	53.77	0.125a	96.17	10.03c	64.09	0.507d	1.14
Paszków CONV	819.0cd	54.03	138.2c	53.75	0.115a	67.64	16.50c	37.20	0.448e	7.78
Słońsk ORG	2 416.0a	39.63	551.4a	51.30	0.120a	94.28	142.28a	41.69	0.552bc	4.35
Jary ORG	613.0de	54.48	123.0c	62.08	0.150a	56.57	18.80c	72.54	0.525cd	13.67
Mean	1 131.17		237.92		0.1333		60.44		0.5312	
$LSD_{0.05}$	336.7		62.22		0.2202		26.15		0.0279	

Means followed by the same letters are not significantly different

The average seed yield was from 10.03 (Paszków organic) to 142.28 g·m^{-2} (Słońsk organic) and the biggest seeds (weight of 1000 seeds) were obtained organically in Plewiska (0.590 g) while the smallest were conventional from Paszków (0.448 g) (fig. 1 and tab. 2). In both location seed yields were comparable and there were no significant differences. The weight of 1000 seeds of organic seeds was significantly higher compared with the conventional seeds in both locations.

The positive correlation was found between the fresh and dried herb yield, fresh herb yield and seed yield, fresh herb and weight of 1000 seeds, dried herb yield and seed yield, seed yield and weight of 1000 seeds. Only dried herb yield was not significantly correlated with the weight of 1000 seeds (tab. 3).

Table 3. The correlation matrix for the quantitative traits of lemon balm

Trait	Fresh herb yield	Dried herb yield	Seed yield
Dried herb yield	0.789***		
Seed yield	0.732***	0.731***	
Weight of 1000 seeds	0.422*	0.310	0.571***

* – P < 0.05; *** – P < 0.001

Table 4. Mean values and coefficients of variation (cv) for lemon balm essential oil content and its composition (2008–2010)

Trait		Location						$LSD_{0.05}$
		Plewiska ORG	Plewiska CONV	Paszków ORG	Paszków CONV	Słońsk ORG	Jary ORG	
Ess. oil (ml·100 g^{-1} sm.)	mean	0.145a	0.145a	0.125a	0.115a	0.120a	0.150a	0.2202
	cv	43.89	43.89	96.17	67.64	94.28	56.57	
Linalool (%)	mean	15.58a	6.09a	2.87a	1.27a	10.97a	1.39a	39.8
	cv	112.4	102.9	*	*	101.3	*	
Geranial (%)	mean	9.64a	11.07a	15.55a	23.26a	8.84a	22.86a	6.55
	cv	67.44	120.73	36,25	*	99.51	*	
Citronellol (%)	mean	5.73	5.42a	3.92a	6.02a	7.27a	8.53a	25.22
	cv	1.85	48.97	36.66	*	49.93	*	
Caryophyllene (%)	mean	6,94	21.88a	33.53a	17.22a	11.12a	17.46a	38.79
	cv	74.94	40.05	77.56	*	9.34	*	
Neral (%)	mean	13.31a	21.71a	18.11a	34.67a	14.17a	40.32a	54.83
	cv	122.5	94.4	129.40	*	127.2	*	
Geraniol (%)	mean	1.14a	0.39a	0.45a	0.26a	0.45a	0.42a	1.19
	cv	50.86	49.59	49.26	*	*	*	
Citronellal (%)	mean	1.8a	1.20c	1.87a	1.39bc	1.65ab	1.11c	0.3498
	cv	10.21	7.07	1.137	*	9.03	*	
Other (%)	mean	45.88a	32.25a	25.16a	15.91a	45.76	7.91a	39.09
	cv	21.45	66.93	26.27	88.3	29.7	*	

Means followed by the same letters are not significantly different

Essential oil content of the herb ranged from 0.115 (Paszków conv.) to 0.150 ml·100g^{-1} sm. (Jary organic) (fig. 1 and tab. 4). Lemon balm herbs obtained from organic cultivation contained more essential oil that conventional herbs, although no significant differences were noticed, while in Plewiska there were no differences in oil content at all. These results are similar to those given by Dachler and Peltzman [1999]: 0.01–0.25% of essential oil in lemon balm herb. The results of essential oil content in dry leaves (0.15 ml·100g^{-1} sm.) were similar to those reported by Carnat et al. [1998]. Patora et al. [2003], who evaluated different population of lemon balm grown in Poland, reported that the content of essential oil was from 0.08 to 0.25% in leaves and from 0.06 to 0.17% in herb. Saglam et al. [2004], who examined the effect of plant density and propagation method, obtained 0.20–0.28% of essential oil in dry leaves and there was no significant effect of any treatment observed. The data presented by Cosge et al. [2009] showed that investigated plant material of lemon balm grown in Turkey contained from 0.04 to 0.10% of essential oil. The investigation on organic cultivation of three cultivars of lemon balm done by Reneau [2003] showed that the content of essential oil varied from 0.05 (cv.'Quedlinburger Niederliegende') to 0.10% (cv.'Common'). The application of the composted horse manure did not affect on essential oil content or herb quality.

Table 5. The correlation matrix for the lemon balm essential oil content and its composition (2008–2010)

Trait	Ess. oil	Linalool	Citronellol	Geranial	Caryo-phyllene	Neral	Geraniol	Citronellal
Linalool	-0.8153*							
Citronellol	-0.4825	-0.2789						
Geranial	0.08561**	-0.7533*	0.6737					
Caryophyllene	-0.0692	-0.4455	-0.2117	-0.0312				
Neral	0.9127**	-0.8741**	0.6108	0.9645***	0.1479			
Geraniol	-0.3937	0.8262*	0.0283	-0.4036	-0.828*	-0.5582		
Citronellal	-0.108	0.4709	-0.4868	-0.3014	-0.6868	-0.4023	0.5331	
Other	-0.756*	0.7528*	-0.6963	-0.9362***	-0.2383	-0.947***	-0.370	0.5367

* – P < 0.05, ** – P < 0.001, *** – P < 0.001

Seven, main active compounds identified in lemon balm essential oil of all organic and conventional herbs contributed from 54.12 to 92.09% of the gas chromatography profile. The main component of essential oil obtained from lemon balm herb was neral which reached from 13.31 (Plewiska organic) to 40.32% (Jary organic) (fig. 1 and tab. 4). Content of caryophyllene oscillated from 6.94 (Plewiska organic) to 33.53% (Paszków organic) and content of geranial – 8.84 (Słońsk organic) to 23.26% (Paszków conv.). Content of linalool varied from 1.27 (Paszków conv.) to 15.58% (Plewiska organic) and content of citronellol was from 3.92 (Paszków organic) to 8.53% (Jary organic). Another detected compounds was citronellal – from 1.11 (Jary organic) to 1.87% (Paszków organic) and geraniol which ranged from 0.26 (Paszków conv.) to 1.14% (Plewiska organic). In both locations, Paszków and Plewiska the content of geraniol, linalool and citronellal was higher in organic lemon balm herbs, while the content of neral and geranial was higher in conventional raw materials of lemon balm. The content of essential oil was positively correlated with geranial and neral, but negatively correlated with linalool. The positive correlation of the following compounds was found: linalool and geraniol, geranial and neral. While negatively was correlated linalool with geranial and neral, geraniol and caryophyllene (tab. 5).

Different composition of the main compounds were found by Carnat et al. [1998]: citral 48.00 (neral + geranial), citronellal 39.47 and caryophyllene 2.37%. Moradkhani et al. [2010] determined the main components of lemon balm essential oil at 39% of citronellal, 33% of citral and 2% of geraniol. Cosge et al. [2009] recorded citronellal (36.6–43.7%), citral (10.1–17.4%), thymol (0.4–11.9%) and caryophyllene (5.9–7.2%) as major components.

Results presented by Kazimierczak et al. [2014] indicated that organic lemon balm herb contained more vitamin C, phenolic acids and flavonoids, while less carotenoids, compared with conventional herbs. These authors did not analyze content of essential oil.

Table 6. Microbiological contamination of lemon balm herb 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	after harvest	after 6 month	
Plewiska ORG	3 100	1 500	160	60	80	40	–	–	–
Plewiska CONV	580	130	160	50	300	40	–	–	–
Paszków ORG	45 000	60	240	10	3 800	200	–	–	–
Paszków CONV	55 000	400	110	10	24 400	230	–	–	–
Słońsk ORG	310 000	4 300	500	145	31 000	600	10	–	–
Jary ORG	1 300	1 200	140	10	10	10	–	–	–
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 lemon balm herb after harvest, then after 6 months of storage showed a great diversification of microbiological contamination of raw material, depending on the herb origin (tab. 6). In total, the most contaminated lemon balm herb originated from Słońsk organic, even presence of *Escherichia coli*, after harvest, was determined, while the best herb was from Plewiska conventional.

The herb from Słońsk organic was the most contaminated by aerobic bacteria and the lowest one – from Plewiska conventional. In all lemon balm herbs the total contamination of fungi (yeasts and moulds) was not too high: the highest amount were noted in the case of herb from Słońsk organic, while the herb from Paszków conventional was less contaminated. The contamination of *Enterobacteriaceae* in the herb from Słońsk organic was the highest, and the presence of *Enterobacteriaceae* in herb from Paszków control was also high. Though, all of the investigated lemon balm raw materials were below the level of standard contamination A (raw materials treated with hot water). While, *Enterobacteriaceae* contamination of herbs from organic experiments of Paszków and Słońsk and Paszków control was exceeded according to standard B (raw material not treated with hot water). Also the herb from Słońsk organic did not comply with standard B for aerobic bacteria content [European Pharmacopoeia 7.0 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 lemon balm herbs 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. The contamination of *Escherichia coli* is not accepted for good quality of medicinal plant raw material of any system of cultivation.

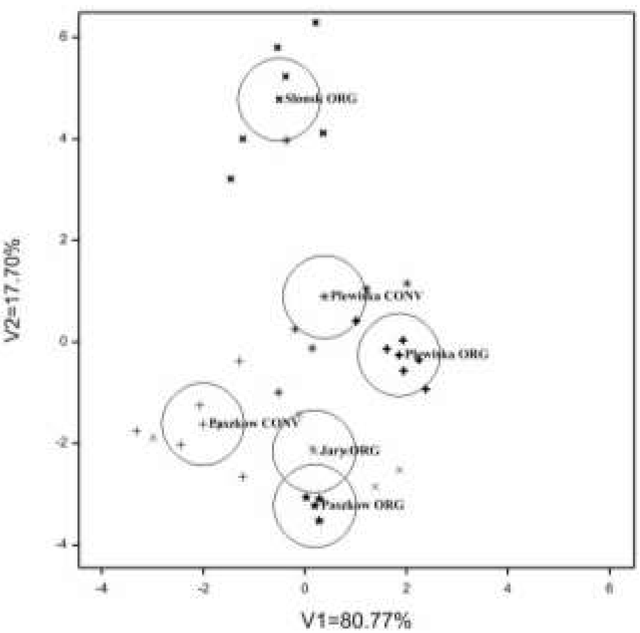

Fig. 2. Plots' mean and unit scores from a canonical varieties analysis of six locations; the circles mean 95% confidences interval

The results of multidimensional analysis of the studied locations in respect of 13 traits simultaneously showed that the first and second canonical varieties elucidated 80.77 and 17.70%, respectively, of multivariate variability of location (fig. 2). The biggest variation of observations was observed in organic experiment in Słońsk, while the smallest in organic experiment in Plewiska (fig. 2).

CONCLUSIONS

1. Herb yield of lemon balm from conventional cultivation was significantly higher compared with the yield from organic experiments.
2. The content of essential oil in herbs obtained from both systems of cultivation was comparable.
3. The content of two main compounds: neral and geranial was higher in essential oil of conventional herbs.
4. The satisfied yield of lemon balm seeds was obtained in organic experiments and organic seeds were bigger then the conventional ones.
5. The herbs of lemon balm were below the level of standard contamination for raw materials do not treated with hot water (B) according to European Pharmacopoeia 7.

ACKNOWLEDGMENTS

The project was financed by Polish Ministry of Agriculture and Rural Development.

REFERENCES

Abbaszadeh, B., Farahani, H.A., Valadabadi, S.A., Darvishi, H.H. (2009). Nitrogenous fertilizer influence on quantity and quality values of balm (*Melissa officinalis* L.). J Agri. Ext. Rural Dev., 1(1), 31–33.

Aziz, E., El-Ashry, S.M. (2009). Efficiency of slow release urea fertilizer on herb yield and essential oil production of lemon balm (*Melissa officinalis* L.) plant. Am. Eur. J. Agric. Environ. Sci., 5 (2), 141–147.

Bocianowski, J., Szulc, P., Nowosad, K. (2015). Parallel coordinate plots of maize traits under different magnesium applications. J. Integr. Agricult., 14(3), 593–597. doi: 10.1016/S2095-3119(14)60852-2.

Brandt, K., Molgaard, J.P. (2001). Organic agriculture: does it enhance or reduce the nutritional value of plant foods? J. Sci. Food Agric., 18, 924–931.

Carnat, A.P., Carnat, A., Fraisse, D., Lamaison, J.L. (1998). The aromatic and polyphenolic composition of lemon balm (*Melissa officinalis* L. subsp. *officinalis*) tea. Pharm. Acta Helv., 72, 301–305.

Cosge, B., Ipek, A., Gurbuz, G. (2009). GC/MS analysis of herbage essential oil from lemon balm (*Melissa officinalis* L.) grown in Turkey. J. App. Biol. Sci., 3(2), 136–139.

Dachler, M., Pelzmann, H. (1999). Arznei- und Gewurzpflanzen. Agrarverlag Klosterneuburg.

European Pharmacopoeia, 7th edn. (2010). Council of Europe, Strasburg.

Herms, D.A., Mattson, W.J. (1992). The dilemma of plants: to grow or defend. Q. Rev. Biol., 67, 283–335.

Kabata-Pendias, A., Pendias, H. (1999). Biogeochemia pierwiastków śladowych. Wyd. Nauk. PWN, Warsaw.

Kazimierczak, R., Hallmann, E., Rembiałkowska, E. (2014). Effect of organic and conventional production systems on the content of bioactive substances in four species of medicinal plants. Biol. Agric. Hort., doi: 10.1080/01448765.2014.977948.

Kędzia, B. (1999). Badania nad zanieczyszczeniem surowców zielarskich drobnoustrojami. IRiPZ, Poznań.

Kozak, M., Bocianowski, J., Sakwojć, S., Wnuk, A. (2010). Call for more graphical elements in statistical teaching and consultancy. Biomet. Lett., 47(1), 57–68.

Kozak, M., Bocianowski, J., Rybiński, W. (2013). Note on the use of coefficient of variation for data from agricultural factorial experiments. Bulgar. J. Agricult. Sci., 19(4), 644–646.

Kozik, E., Golcz, A. (2011). Plant nutrients. In: Research Methods in Plant Sciences (vol. 3). Narwal, S., Politycka, B., Fengzhi, W., Sampietro, D. (eds). Studium Press LLC, Houston, 9–41.

Król, B. (2010). Melisa lekarska In: Uprawa ziół. Poradnik dla plantatorów, Kołodziej, B. (eds.). PWRiL, Poznań, 294–298.

Moradkhani, H., Sargsyan, E., Bibak, H., Naseri, B., Sadat-Hosseini, M., Fayazi-Barjin, A., Meftahizade, H. (2010). *Melissa officinalis* L., a valuable medicine plant: A review. J. Med. Plants Res., 25(4), 2753–2759.

Nowosielski, O. (1988). Fertilization recommendation in horticulture. PWRiL, Warsaw, 45–72.

Patora, J., Majda, T., Gora, J., Klimek, B. (2003). Variability in the content and composition of essential oil from lemon balm (*Melissa officinalis* L.) cultivated in Poland. J. Endocrinol. Invest., 26(10), 950–955.

Reneau, E. (2003). Growing essential crops organically: perspectives from frontier. Proceedings of 3rd National Small Farm Conference Albuquerque, New Mexico 17–20.09.2003, pp.13–19.

Saglam, C., Atakisi, I., Turhan, H., Kaba, S., Arslanoglu, F., Onemli, F., 2004. Effect of propagation method, plant density and age of lemon balm (*Melissa officinalis* L.) herb and oil yield. New Zeal. J. Crop Hort. Sci., 32(4), 419–423.

Seidler-Łożykowska, K., Mordalski, R., Kucharski, W., Golcz, A., Kozik, E., Wójcik, J. (2009). Economic and qualitative value of the raw material of chosen species of medicinal plants from organic farming. Part I. Yield and quality of garden thyme herb (*Thymus vulgaris* L.). Acta Sci. Pol., Agricultura, 8(3), 23–28.

Seidler-Łożykowska, K., Mordalski, R., Kucharski, W., Kędzia, B., Bocianowski, J. (2014). Yielding and quality of lavender flowers (*Lavandula angustifolia* Mill.) from organic cultivation. Acta Sci. Pol., Hortorum Cultus, 13(6), 173–183.

Shapiro, S.S., Wilk, M.B. (1965). An analysis of variance test for normality (complete samples). Biometrika, 52, 591–611.

VSN International (2014). GenStat Reference Manual (Release 17). VSN International, Hemel Hempstead, UK.

WPŁYW UPRAWY EKOLOGICZNEJ NA PLONOWANIE I JAKOŚĆ SUROWCA MELISY LEKARSKIEJ (*Melissa officinalis* L.)

Streszczenie. Surowce zielarskie powinny spełniać coraz wyższe wymagania jakościowe przetwórców, które dotyczą szczególnie zawartości substancji czynnych, plonu surowca i zanieczyszczeń: mikrobiologicznych, metalami ciężkimi lub pestycydami. Te rosnące wymagania mogą spełnić surowce pochodzące ze zbioru lub upraw ekologicznych. Głównym celem badań była ocena i porównanie wartości surowca melisy lekarskiej pochodzącej z uprawy ekologicznej i konwencjonalnej. W latach 2008–2010 oceniano plonowanie i jakość melisy lekarskiej 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 i skład olejku eterycznego w suchym surowcu oraz poziom zanieczyszczeń mikrobiologicznych surowca. Plon ziela melisy z doświadczeń ekologicznych był mniejszy w porównaniu z uprawą konwencjonalną, natomiast zawartość olejku eterycznego w zielu pochodzącym z obu systemów uprawy był podobny. Zawartość olejku eterycznego oraz jego skład nie były zależne od systemu uprawy. W doświadczeniach ekologicznych uzyskano satysfakcjonujący plon nasion, a nasiona były większe od kontroli. Badany surowiec melisy spełniał wymogi zanieczyszczeń mikrobiologicznych surowców poddawanych działaniu gorącej wody (A) zgodnie z Farmakopeą Europejską 7.0.

Słowa kluczowe: melisa leksrska, systemuprawy, plon, surowiec, olejek eteryczny

Accepted for print: 25.05.2015

For citation: Seidler-Łożykowska, K., Mordalski, R., Kucharski, W., Kędzia, E., Nowosad, K., Bocianowski J. (2015). Effect of organic cultivation on yield and quality of lemon balm herb (*Melissa officinalis* L.). Acta Sci. Pol. Hortorum Cultus, 14(5), 55–67.