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The Effect of Organic Cultivation on the Contents of Macro- and Micro-elements Studied in Polish Cultivars of Three Medicinal Plants

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ABSTRACT

Experiments were conducted to evaluate the contents of macro-elements [nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sodium (Na), and magnesium (Mg)] as well as micro-elements [iron (Fe), manganese (Mn), copper (Cu), and Zinc (Zn)] in organic herbs of sweet basil (*Ocimum basilicum* L.), savory (*Satureja hortensis* L.) and marjoram (*Origanum majorana* L.). For the chemical analysis, conducted on dry weight basis, the herbs were obtained from the experiments conducted in four certified organic farms in Poland. Among the herbs of basil, savory and marjoram, basil herb contained largest amounts of all macro- and micro-elements except that of Fe, which was maximal in marjoram. The average content of N, P, K, Mg Mn, Cu and Zn was higher in the organic herb compared with the conventional one. Enhanced content of macro- and micro-elements in the tested herbs had significant effect on the herb-quality.

Keywords: basil, content of macro- and micro-elements, conventional and organic cultivation, medicinal plants, marjoram, savory

INTRODUCTION

Mineral components represent a group of compounds which are indispensable in human nutrition. Since the human body is not able to produce the mineral elements, they should be supplied together with food in adequate amounts. The herbs contain significant amounts of mineral substances and are a rich source of easily available mineral nutrients in the daily diet (Kołodziej 1992).

Macro-elements fulfill specific physiological functions. Of the macro-elements, N, P and Ca belong to structural elements, while K, Mg, Na and Ca are the electrolytic macro-elements (Wesołowski 2005). Micro-elements, despite the fact that they occur in negligible amounts, have their functional role rather than structural one in living beings. They take part in the body metabolism as biocatalysts (Griffith 1994; Brzozowska 1998, 1999).

Daily requirement of micro-elements for adults is: 15-18 mg of Fe, 15-20 mg of Zn, 2-4 mg of Cu and 3 mg of Mn (Kołodziej 1992; Ziemlański *et al.* 1998). Fe plays an important role in the activities of many enzymatic systems. It occurs as a factor for storing oxygen in hemoglobin and myoglobin. It also displays redox properties (Kołodziej 1992; Brzozowska 1999). Zn takes part in the transformation of proteins, nucleic acids and fat as well as in the metabolism and assimilation of Fe compounds. Among other important roles, Zn affects the development of the central nervous system, increases the ability to learn and is indispensable in ossification processes and accelerates wound healing. Zn also has a beneficial effect on arteriosclerosis and regulates the development of sexual glands (Griffith 1992; Kołodziej 1992; Brzozowska 1998). Besides, Mn takes part in many biochemical reactions as well as in the transformations of vitamin C. It also activates some oxidation enzymes. Mn deficiency may cause disturbances in the development of bones and sexual organs (Brzozowska 1999). Cu is a component of many enzymes; it is of great importance in the synthesis of red blood cells and has an effect on human immunological system. The proper level of Cu increases the assimilation of Fe. Prolonged deficiency of Cu results in anemia and growth disorders in human beings (Griffith 1992; Kołodziej 1992; Brzozowska 1998, 1999).

Medicinal herbs are a good and natural source of dietary supplements. The investigation done by Jadczak *et al.* (2006) showed different concentration of macro-elements in fresh basil herb. According to them, P content was 0.42%, content of K oscillated from 3.01 to 3.74%, content of Ca ranged from 2.74 to 3.46% and that of Mg from 0.25 to 0.28%. Arceusz *et al.* (2010) analyzed the content of macro- and microelements in 79 raw materials of medicinal plants from different plant families. Their investigation showed that medicinal plants from *Lamiaceae* family were rich in Ca (20 mg/g), Fe (116 mg kg^{-1}) and Zn (83.4 mg kg^{-1}), while these plants contained the lowest amounts of boron (B) (55.5 mg kg^{-1}). Gjorgieva *et al.* (2011), who tested content of metallic trace elements in medicinal plants of Macedonia, concluded that the examined plants were rich in Fe (880 mg kg^{-1}), Mg (4296 mg kg^{-1}), Ca (23279 mg kg^{-1}) and K (28173 mg kg^{-1}) and, therefore, might play important role in maintenance of human health. The results obtained by Nurzyńska-Wierdak *et al*. (2011) showed that K (1.97 – 4.18%) and N (0.21 – 1.59%) contents in basil herb differed with N fertilization and cultivars. Stevovic *et al*. (2010) reported that macro- and micro-elements, present in the herb of tansy, were at different concentrations, viz. P (0.1 – 0.8%), K (2.2 – 4.3%), Ca (0.9 – 3.3%), Mg (0.1 – 1.0%), Na (0.01 – 0.02%), Fe (0.01 – 0.05%), and Mn (0.007 – 0.02%). Medicinal herbs are also a valuable source of macro- and micro-elements in the animal diet. The analysis carried out by Trzaskoś (1997) showed that many of the fodder herbs fully meet or even exceed animal demand for mineral components, improving their well-being.

The main objective of this work was to determine macro- and micro-element content of the herbs of the selected plant spices originated from the organic cultivation in Poland. Although, there are a few references regarding con-

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tents of macro- and micro-element in some herbs and spices, no one concerns the organic herbs.

MATERIALS AND METHODS

Chemicals and reagents

Acetic acid (CH_3COOH), ethylenediaminetetraacetic acid (EDTA), NH_4 solution, and citric acid were purchased from Merck (Poland). Sulphosalicylic acid ($C_7H_6O_6S$), sodium thiosulphate ($Na_2S_2O_3$) and selenium were purchased from Sigma-Aldrich (Poland). Sulphuric acid, nitric acid, and chloric acid were purchased from POCH Gliwice (Poland).

Soil analysis

Before starting experiment, soil samples were collected from each experimental field to determine the content of macro- and micro-elements. Collected samples were chemically analyzed by the universal method according to Nowosielski (1988) and Kozik and Golcz (2011). Extraction of N (N-NH_4, N-NO_3), P, K, Ca, Mg, Cl and Na 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: N-NH_4, N-NO_3 – by microdistillation method with Bremner in Starck's modification (Nowosielski 1988); P – colorimetrically with ammonium vanadomolybdate method (Nowosielski 1988); K, Ca, Na – photometrically (Nowosielski 1988); Mg – by atomic absorption spectrometry (AAS, Carl Zeiss-Jena apparatus, Germany); Cl – nephelometrically using $AgNO_3$ (Nowosielski 1988).

Microelements (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 by potentiometrically (soil: water = 1: 2).

Plant analysis

In 2006-2007, the experiment was carried out in four certified organic farms located at: A: Jary (51°17′ N, 16°52′ E); B: Słońsk (52° 33′ N, 14° 48′ E); C: Wiry (50° 50′ N, 16° 38′ E); and D: Plewiska (52° 21′ N, 16° 48′ E). The experiments were conducted according to randomized block design with three replications. Each plot was of 10 m^2 size. The studies were conducted on three Polish cultivars of medicinal plants, namely, sweet basil (*Ocimum basilicum* L.) cv. 'Kasia', savory (*Satureja hortensis* L.) cv. 'Saturn' and marjoram (*Origanum majorana* L.) cv. 'Miraż'. Each year, the seeds were sown directly into the soil at the following rates: basil – 8 g/plot, savory – 10 g/plot, marjoram – 7 g/plot (Dachler and Pelzmann 1999). The raw material (herbs) obtained from Plewiska (D) through the conventional cultivation, was used as a control. Organic cultivation did not include the use of chemical fertilization and pesticides, while in conventional cultivation the chemical fertilizers were used as per reccomendation. At the beginning of blossom time, herbs (stems + leaves + flowers) were collected from the total area of 10 m^2 of each plot. The herbs were dried in natural conditions in shade and well ventilated place. For the evaluation of the contents of macro- and micro-elements, the dried whole collected herb was subjected to 'wet' mineralization using the following media:

1. In a mixture of 20 mL sulphosalicylic acid ($C_7H_6O_6S$), sodium thiosulphate ($Na_2S_2O_3$) and selenium (Se) in order to determine total N.

2. In concentrated 95% sulphuric acid to determine P, K, Ca, Mg and Na.

3. In a mixture of 95% HNO_3 and 60% $HClO_4$ in 3:1 proportion to determine Fe, Mn, Cu and Zn (Nowosielski 1988).

After the mineralization of plant material, the mineral elements were determined as per the following methods:

1. N content was determined by Kjeldahl distillation method using a Parnas-Wagner apparatus (Nowosielski 1988).

2. P content was determined by colorimetric method using ammonium molybdate according to Schillak method (Nowosielski 1988).

3. K, Ca and Na contents were determined by photometric method (Nowosielski 1988)

4. Mg, Fe, Zn, Cu and Mn were determined by Atomic Absorption Spectrophotometric method (AAS-3) (Nowosielski 1988; Kabata-Pendias and Pendias 1999; Kozik and Golcz 2011).

Statistical analysis

The obtained data were subjected to statistical analysis according to randomized block design using MANOVA test (Hill and Lewicki 2006). All the variables were subjected to analysis of variance to examine the contents of macro- and micro-elements. A student's *t*-test was used to test the significance of differences between various types of cultivations at $P < 0.05$.

RESULTS AND DISCUSSION

Contents of macro- and micro-elements in the soil

During the both years, the soil of all the locations contained trace amounts of NH_4^+ and NO_3^- forms of N (**Table 1**). The soil from location A, having low pH, contained a large amount of K (221.234 mg/L), while the content of Ca (189.105 mg/L) was the lowest. The soil from location C was richest in K (193.183 mg/L), Ca (945.775 mg/L) and Mg (109.187 mg/L) with a neutral pH (pH 7). The soil that belonged to the control samples was richer in all macro-elements compared with organic soil that was brought from the same location (D).

As per **Table 2**, the content of microelements in the tested organic soils was adequate, containing 95–154 mg Fe/L, 8–20 mg Mn/L, 7–13 mg Zn/L, and 8–25 mg Cu/L. The soils of all the locations were rich in Fe. The level of microelements was adequate for most of the crops in all the organic soils. All the soils contained very small amounts of sodium (7–23 mg/L) and chlorine (19–45 mg/L).

Contents of macro- and micro-elements in the herb

The basil herbs contained the largest amounts of all the macro- and micro-elements except that of Fe compared with the herbs of savory and marjoram. Marjoram herb was very rich in Fe (495 – 891 mg kg^{-1}) (**Tables 3**–**5**).

Basil

The average contents of N, P, Mg and some of the micro elements (Fe, Cu and Zn) were higher in the organic herb compared with those of the conventional one (**Table 3**). Macro-element contents of basil herb both from organic and conventional cultivation was higher compared with that cited by Marsh *et al.* (1976). Grzeszczuk and Jadczak (2007) reported that N content of basil herb was 0.92 mg kg^{-1}, which was also much lower, compared to that revealed by our results. Golcz (2009) evaluated basil herbs that were produced by conventional cultivation in different development stages. She reported that the highest content of N, K and Ca of basil herb was found in the phase of intensive growth but in the comparable phase at the beginning of blossom time, the content of N was similar to that obtained in our experiment (2.9%), with the content of K (3.6%) and Ca (2.5%) being comparatively lower. Basil herb contained the largest amount of P in the seed setting phase, while Mg content was the highest in the full flower phase. The content of Mg in comparable phase (at the beginning of blossom time) was much lower (0.42%) compared with the organic basil herbs in our experiment. The content of Fe and Cu of organic herb was higher compared with that of the conventional one; though, Fe and Cu content was lower compared with the results obtained by Marsh *et al*. (1976). Results obtained by Golcz and Seidler-Łożykowska (2009) showed that at the beginning of flowering, the content of Fe (470 mg kg^{-1}), Mn (39 mg kg^{-1}) and Cu (11 mg kg^{-1}) was lower

Table 1 Content of macro-elements in the soil samples [mg/L].

Location	$N\text{-}NH_4$		$N\text{-}NO_3$		P		K		Ca		Mg		pH	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
A	28	15	tr.	2	19	29	221	234	189	105	42	56	5.2	5.4
B	21	5	11	tr.	74	40	132	108	693	463	117	82	6.8	5.7
C	14	10	tr.	6	50	52	193	183	945	775	109	187	7.6	7.0
D	18	8	tr.	tr.	33	33	82	88	245	257	10	64	5.6	6.3
Control	25	7	tr.	tr.	93	68	192	111	469	247	59	46	6.6	5.9

tr. – trace; A, B, C and D are experimental farms where the experiments were conducted (see details in the text)

Table 2 Content of micro-elements in the soil samples [mg/L].

Location	Fe		Mn		Zn		Cu		Na		Cl	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
A	121	118	11	18	8	13	23	12	7	17	41	32
B	144	154	10	8	10	13	14	8	18	23	19	33
C	102	95	15	14	7	13	22	15	11	19	38	44
D	133	124	20	14	8	11	25	16	8	13	40	31
Control	148	143	14	14	6	17	16	19	10	13	31	45

A, B, C and D are experimental farms where the experiments were conducted (see details in the text)

Table 3 Content of macro- [%] and micro-elements [mg kg^{-1}] in the dried basil herb (2006-2007).

Location	N	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn
A	2.92	0.41	5.21	2.26	0.68	0.007	307	270	19.0	143
B	3.18	0.46	2.98	3.31	0.85	0.012	554	73	17.4	110
C	2.79	0.44	4.42	3.11	0.59	0.008	478	66	17.7	67
D	2.74	0.42	3.05	3.45	0.65	0.008	460	302	18.4	95
Control	2.16	0.39	4.07	3.09	0.49	0.009	477	102	13.8	53
LSD	0.65	0.11	1.32	0.87	0.30	0.0008	158	106	4.5	62

A, B, C and D are experimental farms where the experiments were conducted (see details in the text)

Table 4 Content of macro- [%] and micro-elements [mg kg^{-1}] in the dried savory herb (2006-2007).

Locality	N	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn
A	2.70	0.45	3.28	1.26	0.65	0.008	330	131	14.0	130.1
B	3.02	0.39	2.38	2.35	0.56	0.012	634	45	12.4	51.7
C	2.52	0.40	2.20	1.92	0.47	0.008	619	28	13.4	40.6
D	2.74	0.33	2.43	2.29	0.55	0.009	564	164	12.7	59.8
Control	2.81	0.34	2.41	2.72	0.46	0.011	583	75	12.2	35.7
LSD	0.43	0.09	0.85	0.22	0.09	0.0006	209	82	1.3	71

A, B, C and D are experimental farms where the experiments were conducted (see details in the text)

Table 5 Content of macro- [%] and micro-elements [mg kg^{-1}] in the dried marjoram herb (2006-2007).

Locality	N	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn
A	2.87	0.34	2.47	1.58	0.53	0.007	535	134	11.5	111.6
B	2.48	0.28	1.77	2.32	0.44	0.020	704	56	13.3	56.5
C	2.52	0.24	2.35	2.20	0.29	0.007	495	17	11.3	340.6
D	2.43	0.25	1.95	2.12	0.38	0.011	818	248	15.4	55.3
Control	2.57	0.26	2.08	2.41	0.37	0.011	891	120	15.2	36.5
LSD	0.12	0.006	0.52	0.50	0.13	0.0008	189	118	3.7	63

A, B, C and D are experimental farms where the experiments were conducted (see details in the text)

compared with that obtained in our results.

According to Kabata-Pendias and Pendias (1999), Cu content in plant material ranged from 5 to 20 mg kg^{-1} in Polish climatic conditions. The levels of Cu content of the herbs obtained from both the types of cultivations could also be placed in the range set by other authors (Marsh *et al.* 1976; Suchorska-Orłowska *et al.* 2006).

Savory

The average content of P, Mg and some of the microelements (Fe, Cu and Zn) was higher in the organic herb compared with that of the conventional one (**Table 4**). Macro-element content of savory herb, both from organic and conventional cultivation, was higher compared with that cited by Marsh *et al.* (1976). Grzeszczuk and Jadczak (2007) reported that the content of N of savory fresh herb was 114% more as compared to the control. According to the results obtained from conventional cultivation of savory in different development stages Golcz (2009), the highest content of N, K, Ca and Mg was attained in the phase of intensive growth but in the comparable phase at the beginning of flowering, the content of N and K was similar to that obtained in our experiment, while the content of Ca (1.7%) and Mg (0.34%) was comparatively lower. Savory herb contained the largest amount of P in the phase of full flowering, while Mg content was the highest during intensive vegetative growth.

The content of Cu and Zn of organic herb was higher compared with that of the conventional herb. Also, Fe and Cu content was lower compared with that obtained by Marsh *et al.* (1976). Results cited by Golcz and Seidler-Łożykowska (2009) showed that the highest content of Fe, Mn, Cu and Zn was found at full flowering phase. At the beginning of flowering (comparable phase) the content of Fe (260 mg kg^{-1}), Mn (17 mg kg^{-1}) and Cu (6 mg kg^{-1}) was much lower compared with that obtained in our experiment.

Marjoram

Only the average content of Mg and Zn was higher in the organic herb compared with that of the conventional one (**Table 5**). Macro-element content of marjoram herb, obtained both from organic and the conventional cultivation, was higher compared with that cited by Marsh *et al.* (1976). According to Golcz (2009), marjoram herbs obtained from

conventional cultivation in different development stages contained the highest content of all the tested macro-elements in the phase of intensive growth but in the comparable phase of the beginning of flowering, only the content of N was similar to that obtained in our experiment, while the content of K, Ca and Mg was comparatively lower. Marjoram herb also contained the largest amount of P at the beginning of flowering phase.

The content of Fe, Mg and Cu of organic marjoram herb was similar to that of the conventional herb. Golcz and Seidler-Łożykowska (2009) reported the highest content of Fe and Zn at the beginning of flowering phase, while the highest content of Mg and Cu was found in the seed setting phase. At the beginning of flowering (comparable phase), the content of Mg was much lower compared with that obtained in our experiment.

CONCLUSIONS

Compared with savory and marjoram herbs, basil herb contained the largest amounts of all macro- and micro-elements with the exception of Fe. Marjoram herb, especially the one that was obtained by conventional cultivation technique, was very rich in Fe. The average content of N, P, K, Mg and some of the micro-elements (Mn, Cu and Zn) was higher in the organic herb compared with that of the conventional one.

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