ISSN 1644-0692
www.acta.media.pl
ACTA Acta Sci. Pol. Hortorum Cultus, 14(3) 2015, 141-156

YIELD AND QUALITY OF THE SUMMER SAVORY HERB (*Satureia hortensis* L.) GROWN FOR A BUNCH HARVEST

Katarzyna Dzida[1], Grażyna Zawiślak[1],
Renata Nurzyńska-Wierdak[1], Zenia Michałojć[1], Zbigniew Jarosz[1],
Karolina Pitura[1], Katarzyna Karczmarz[2]
[1]Lublin University of Life Sciences
[2]The John Paul II Catholic University of Lublin

Abstract. The quality of fresh herbs used mainly as food products, is dependent on a number of factors, including the agronomic and environmental ones. The pharmacopoeial material of summer savory is the whole or ground herb, which besides essential oil, contains many other biologically active compounds, such as tannins, carotenoids, flavonoids, and minerals. The aim of the study was to evaluate the yielding of summer savory intended for bunches harvest and mineral composition of the raw material depending on the sowing time and harvesting time. The savory seeds were sown directly into the field on two dates: 23 April and 7 May 2010–2011. The raw material was collected twice: on 1 July and 16 August. Both the first sowing date and the first harvest date affected most preferably the yield of fresh savory herb. Biological value of the ground herb was high and depended on the time of plant harvest. Significantly the greatest content of L-ascorbic acid (39.60 mg 100 g^{-1} FW), chlorophyll a + b (88.25 mg 100 g^{-1} FW), carotenoids (26.15 mg 100 g^{-1} FW), and essential oil (1.79 ml 100 g^{-1}) was found at plants from the first harvest. More nutrients were found at savory plants collected in the first date as compared to the second date. The results show the possibility of using the dry summer savory herb as a source of microelements in a human diet. Analyzing all test parameters affecting the quality of raw material, it is clear that the savory plants used for bunches should be collected at the beginning of July, regardless of the sowing date.

Key words: medicinal plants, sowing date, harvest date, active substances, macronutrients, microelements

Corresponding author: Katarzyna Dzida, Department of Horticultural Plants Cultivation and Fertilization, University of Life Sciences in Lublin, Leszczyńskiego 58, 20-068 Lublin, Poland, e-mail: katarzyna.dzisa@up.lublin.pl

INTRODUCTION

Production of herbal plants in Poland covers an area of about 30 thousand hectares and includes the cultivation of nearly 70 species of medicinal plants. Organic cultivation of herbs, often offering higher yields and better quality raw material is very popular [Seidler-Łożykowska et al. 2009]. The interest in herbal raw materials is increasing due to their growing use as ingredients of herbal teas, dietary supplements, and natural food additives. According to data from the World Health Organization, about 70% of the world population is currently using plants for medicinal purposes [Wills et al. 2000]. Spice plants, harvested at different stages of their development, are usually used fresh or after drying. Fresh spices are more valuable than dried, because they contain more vitamins (especially vitamin C) and essential oils. The biological value of herbs depends on various factors, including the agronomic ones (position, soil, sowing date, harvest date) and climate. Currently, the subjects of scientific research are the active ingredients of herbs: polyphenols [Atanassova et al. 2011], chlorophylls [Kadam et al. 2013], carotenoids [Daly et al. 2010], essential oil [Mahboubi and Kazempour 2011, Sadeghi et al. 2013], ascorbic acid [Veeru et al. 2009], evaluated at different variants of their variability. These components, with broad and strong biological activity, determine the quality and use of raw materials. The species synthesizing above listed active compounds is summer savory (*Satureia hortensis* L.), an annual plant reaching up to 40 cm of height [Gontaru et al. 2008]. Essential oil contained in the plant gives a distinctive herbal-spicy aroma [Mahboubi and Kazempour 2011].

Back to natural medicine has increased the interest in factors affecting the quality of harvested raw materials and on human health. The primary factors influencing on the health of living beings include: heredity, environment, and lifestyle. A diet low both in organic and mineral compounds is the basis of etiology of many diseases, including atherosclerosis, hypertension, diabetes, obesity. Of the 92 natural elements within the geosphere, 26 are considered to be permanent and necessary components of living organisms [Solomons and Ruz 1998]. Micronutrients play a key role in a body of humans, animals, and plants, and particularly in the regulation of cellular metabolism. Disturbances in the bio-element economy lead to disturbances in the functioning of cells and the occurrence of disease symptoms. The source of many nutrients necessary for human life are fruits, vegetables, and herbs. Summer savory (*Satureia hortensis* L.) is the representative of plants from Lamiaceae family, which has highly significant nutritional and taste values. Its pharmacopoeial raw material is herb (*Satureiae herba*), the whole or ground, which besides essential oil, contains many other biologically active compounds, and minerals like calcium, potassium, magnesium, iron, and zinc [Mulas 2006, Ziombra and Frąszczak 2008]. Most of the spice and medicinal species is subjected to processing by drying or freezing. When storing the plant material, physical, biochemical, and microbiological processes occur in them, which change their chemical composition. Behavior of these compounds depends on many factors: species and varieties of plant, as well as the way of their storage [Telesiński et al. 2013]. Also the development phase of plant determines the biological value of crops. The contents of both the primary and secondary metabolites at plants depends on the growth and development of the vegetative and generative parts of a plant. Plants harvested before flowering, at the early stages of flowering and full flowering, are characterized by diverse content of dry matter and minerals. The most abundant in the intense aroma and intact flavor are herbs eaten as fresh; these plants are characterized by higher content of vitamins and unreduced amounts of essential oils.

Summer savory is cultivated in many regions of the world, mainly as a valuable spice and an important component of various aromatic mixtures [Sahin et al. 2003, Hadian et al. 2008]. In a view of constantly growing interest in the cultivation of herbal plants, and the lack of sufficient literature data on the cultivation of herbs for bunches, studies were undertaken to assess the impact of sowing date and harvest date on yielding of summer savory grown for bunches as well as biological value of the test plants.

MATERIAL AND METHODS

The field experiments were conducted in 2010–2011 in the Experimental Farm Felin owned by University of Life Sciences in Lublin (51º25' N 22º56' E). The study object consisted of summer savory plants (*Satureia hortensis* L.). Savory seeds were from PNOS Ożarów Mazowiecki. The direct sowing into the field was performed on two dates: 23 April and 7 May. The standard for seed sowing was 8 kg h^{-1}. Seeds were sown in rows every 30 cm. The size of each plot was 2.4 m^2. The first plant emergence was observed after 3 weeks. The experiment was setup in a randomized block arrangement in four replications. The soil under cultivation was prepared according to the agronomic recommendations for the species: deep plowing was carried out before the plantation foundation, cultivator was used in early spring followed by harrowing. Phosphorus and potassium fertilizers were applied in one dose before plantation foundation: 26.4 kg P ha^{-1} in the form of granular triple superphosphate, 74.7 kg K ha^{-1} in the form of potassium sulfate. Nitrogen fertilizers (70 kg N ha^{-1}) in the form of ammonium nitrate was used in a divided dose: ½ dose before seed sowing and ½ after plant emergence. During the growing season, manual and mechanical weeding as well as soil loosening was conducted. No chemical means for plant protection were applied.

Savory was collected twice, 1 July and 16 August. The herb was cut at a height of 5 cm above the soil surface (on the first harvest date) and 8 cm above the soil (on the second harvest date). After harvesting, the fresh herb yield was determined, and then the herb was dried in a kiln at the temperature of 35°C. After drying, the raw material was ground on sieve with 4 mm mesh diameter to give ground herb.

Contents of the following items were determined in fresh herb:

– L-ascorbic acid – spectrophotometric method according to J.H. Roe with Ewelin's modification [Korenman 1973]; absorbance was measured at 520 nm wavelength;

– Chlorophylls and carotenoids – spectrophotometric method [Lichtenthaler and Wellburn 1983]; absorbance was measured at λ = 662 nm (chlorophyll a) and λ = 645 nm (chlorophyll b) as well as λ = 470 nm for carotenoids.

Dried herb of summer savory was subject to determination of:

– Essential oil – hydro-distillation method [Farmakopea Polska VII 2006]; distillation duration – 3 hours, sample size – 20 g of ground herb and 400 ml of distilled water.

After harvesting, the effect of examined factors (sowing and harvest dates) on the yield of air-dry herb was determined, as well as the content of macro- and micronutrients along with soil chemical analyzes for the contents of available nutrients, were performed. Mineral compounds content in the soil prior to planting was ($mg \cdot dm^{-3}$): $N\text{-}NH_4$ – tr., $N\text{-}NO_3$ – 19, $P\text{-}PO_4$ – 16, K – 23, Ca – 280, Mg – 28 and EC ($mS \cdot cm^{-1}$) – 0.01, pH (in H_2O) 6.02.

Soil analysis. Chemical analyzes of soil were made in 0.03 M acetic acid extract with addition of activated carbon at a ratio of 1:10 (solution to substrate); following items were determined in the resulting solution: $N\text{-}NH_4$, $N\text{-}NO_3$, P, K, Ca, Mg, $S\text{-}SO_4$, Cl. Nitrate and ammonia nitrogen were determined by means of Bremner's microdistillation method with Starck's modification, phosphorus with ammonia vanadomolybdate, while sulfur with barium chloride and chlorides with silver nitrate were determined colorimetrically (spectrocolorimeter Nicolet Evolution 300). Contents of K, Ca, Mg were determined by means of AAS technique (Analyst 300 Perkin Elmer), pH (H_2O) and EC ($mS \cdot cm^{-1}$) values were determined in soil suspended in distilled water in 1:2 ratio [Nowosielski 1988].

Plant material analysis. After drying and grinding the savory plant material, following items were determined: N-total applying Kjeldahl method using Kjeltec 2002 Distilling System Unit. After combusting of the plant material at a temperature of 200°C, then dry-digestion at 450°C [Ostrowska et al. 1991] and cooling down, the ash was treated with hydrochloric acid diluted at 1:2 ratio. The extract was subject to determination of: P, K, Ca, and Mg. Moreover, the 2% acetic acid extract was used to determine the contents of $N\text{-}NH_4$, $N\text{-}NO_3$, $S\text{-}SO_4$, and Cl. Determinations of $N\text{-}NH_4$, $N\text{-}NO_3$, $S\text{-}SO_4$, Cl, as well as P, K, Ca, and Mg were performed applying the same methods as for soil analysis.

Results referring to soil and plant material analyses were statistically processed using variance analysis for k-fold cross-classification. The significance of differences was assessed using Tukey's confidence intervals at the significance level $\alpha = 0.05$.

RESULTS AND DISCUSSION

Yielding of vegetables and spices grown for bunches is very diverse, which results from the responses of individual plant species to growing conditions (position, soil, temperature, precipitation), as well as the methods of cultivation. The results obtained by Jadczak and Grzeszczuk [2009] as well as previous studies [Nurzyńska-Wierdak et al. 2012a, b, c] indicate that spice plants from earlier sowing dates have a higher yield of fresh herb and a higher content of sugars, L-ascorbic acid, chlorophyll, and essential oil than those grown from later sowing dates. This was also confirmed in present study, in which a significant effect of tillage on the yield of fresh savory herb, was found. Significantly higher yield of fresh herb was obtained from the first sowing date (23.04) and the first harvest date (1.07) (tab. 1). At the same time, there was no significant effect of interaction of studied factors on the yield of fresh savory herb. An inverse relationship using different sowing dates on the tarragon yield was shown by Jadczak and Grzeszczuk [2008]. In addition, Jadczak [2007] found no remarkable effect of the cultivation date on savory plant weight, but finding the largest share of leaves in the raw material yield in the cultivation from the earliest sowing. In turn, Krężel and Kołota [2000], when analyzing the impact of sowing the seed of beetroot for bunches, found no significant effect of the test factor on the total and commercial yields of plants. These results indicate the need to conduct further studies with regard to the different dates of sowing and harvesting of spices in order to identify the most optimal ones.

Based on the study, it was found a significant effect of the first sowing date and the first harvest date on yield of ground savory herb (25.37 kg 100 m^{-2}) and the significant impact of these factors on dry herb yield (33.0 kg 100 m^{-2}), as well as the share of ground herb in dry herbs yield (76.87%) (tab. 1). Similar dependencies were demonstrated applying different sowing and harvesting dates of summer savory by Ziombra and Frąszczak [2008]. The authors reported the highest yield of dry herb from plants grown in the first date of sowing and harvested before flowering and early flowering as compared to the full flowering. Martyniak-Przybyszewska and Majkowska-Gadomska [2006] did not find any significant impact of the growing date on the weight of summer savory and marjoram plants, but greater yield of dry savory raw material obtained from the second date of sowing and planting, while first date for marjoram. Jadczak and Grzeszczuk [2008] on the base of the obtained results, observed no effect of sowing date on the content of leaves in the main yield of tarragon. Using different dates of coriander sowing, it was found that plants accumulate less dry matter in the herb at a shorter vegetation period [Nurzyńska-Wierdak et al. 2012c, Telci and Hisil 2008].

The biological value of the utility crops is one of the most important aspects of cultivation. Furthermore, the therapeutic efficacy of plants is regarded as more important than the yield [Wills et al. 2000]. An important indicator of the herbs, vegetables, and fruits quality is the content of L-ascorbic acid [Veeru et al. 2009]. The concentration of this component at plants changes under the influence of genetic, ontogenetic, and growing factors [Nurzyńska-Wierdak et al. 2012a, b, c]. The harvest date of savory plants impacted significantly on all biotic parameters of the yield (tab. 2). Savory herb contained from 29.36 to 40.25 mg of L-ascorbic acid × 100 g^{-1} FW. Higher levels of this compound were shown in the herb harvested in early July than in mid-August. Savory plants cultivated near Olsztyn were characterized by considerably lower content of this component: 16.2 mg 100 g^{-1} FW [Martyniak-Przybyszewska and Wojciechowski 2004], which could be associated with different cultivation conditions. Concentration of L-ascorbic acid is determined genetically and dependent on the raw material harvest stage [Nojavan et al. 2008, Nurzyńska-Wierdak et al. 2012a]. Veeru et al. [2009] reported L-ascorbic acid level in plant extracts from 3.86 to 21.33 mg 100 g^{-1} FW, along with the highest antioxidant activity for the extract most abundant in this component. Given the above data, fresh summer savory herb can be considered a good source of L-ascorbic acid and promising health-promoting material.

Chlorophyll a and chlorophyll b are the two main pigments found at plant together with carotenoids in chloroplasts. Genetic and environmental factors are the key factors during the chlorophyll synthesis process [Kadam et al. 2013]. Chlorophyll content in herbs depends largely on the type of raw material (plant species, utility organ) as well as light conditions. Biological activity of chlorophyll is related to its antioxidant properties, and the consumption of foods abundant in this component is recommended for the

Table 1. Yield and biological value of fresh herb of summer savory (mean for 2010 and 2011)

Sowing date*	Harvest date*	Yield of fresh herb (kg 100 m^{-2})	Yield of dry herb (kg 100 m^{-2})	Yield of herb without stems (kg 100 m^{-2})	Share of herb without stems in dry herb (%)
I	I	159.62	33.00	25.37	76.87
	II	111.00	21.50	15.00	69.76
Mean		135.31		27.25	20.18
II	I	130.37	25.00	16.25	65.00
	II	86.50	21.37	14.25	66.68
Mean		108.43		23.18	15.25
Mean	I	144.99	29.00	20.81	70.93
	II	98.75	21.43	14.62	68.22
Mean		121.87	25.21	17.71	69.57
$LSD_{0.05}$					
sowing date		17.677		n.s.	4.882
harvest date		17.677		6.576	4.882
interaction		n. s.		n.s.	n.s.

* – sowing date: 23.04.; 07.05; harvest date: 01.07; 18.08.; f.w. – fresh weight, a.d.w. – air dry weight, n.s. – not significant

Table 2. The pigments concentration in fresh herb of summer savory (2010–2011)

Sowing date*	Harvest date*	L-ascorbic acid (mg 100 g^{-1} f.w.)	Essential oil (ml 100 g^{-1} a.d.w.)	Chlorophyll a (mg 100 g^{-1} f.w.)	Chlorophyll b (mg 100 g^{-1} f.w.)	Chlorophyll a + b (mg 100 g^{-1} f.w.)	Carotenoids (mg 100 g^{-1} f.w.)
I	I	40.25	1.87	59.06	30.55	89.61	26.40
	II	31.16	1.65	50.47	26.97	77.44	21.40
Mean		73.31	1.76	54.76	28.76	83.52	23.90
II	I	38.96	1.72	57.48	29.41	86.89	25.90
	II	29.36	1.56	49.33	28.56	77.89	22.65
Mean		65.84	1.64	53.40	28.98	82.39	24.27
Mean	I	39.60	1.79	58.27	29.98	88.25	26.15
	II	30.26	1.60	49.90	27.76	77.66	22.02
Mean		34.93	1.70	54.08	28.87	82.95	24.08
$LSD_{0.05}$							
sowing date		–	0.850	n. s.	n. s.	n. s.	n. s.
harvest date		–	0.850	4.885	1.229	5.860	3.143
interaction		–	n. s.	n. s.	1.231	n. s.	n. s.

* – sowing date: 23.04.; 07.05; harvest date: 01.07; 18.08.; f.w. – fresh weight, n.s.– not significant

Table 3. The chemical composition of summer savory grown for bunches (mean for 2010 and 2011)

Sowing date*	Harvest date*	% d.m.									*mg·kg^{-1} d.m.			
		N-total	Zn	Zn	Zn	Zn	Ca	Mg	S	Cl	Zn*	Fe*	Mn*	Cu*
I	I	3.95	60.05	60.05	60.05	60.05	2.52	0.32	0.02	0.01	60.05	929.67	49.87	5.792
I	II	3.50	63.47	63.47	63.47	63.47	1.49	0.29	0.07	0.05	63.47	1642.00	56.91	8.040
Mean for sowing date I		3.72	0.08	61.76	61.76	61.76	61.76	0.30	0.04	0.03	61.76	1285.83	53.39	6.916
II	I	3.96	49.27	49.27	49.27	49.27	1.55	0.32	0.06	0.09	49.27	1390.01	52.33	6.067
II	II	3.59	55.57	55.57	55.57	55.57	1.41	0.29	0.04	0.09	55.57	880.02	43.74	7.602
Mean for sowing date II		3.77	0.08	52.42	52.42	52.42	52.42	0.30	0.05	0.09	52.42	1135.01	48.03	6.835
Mean for harvest date	I	3.95	54.66	54.66	54.66	54.66	2.03	0.32	0.04	0.05	54.66	1159.84	51.10	5.930
	II	3.54	59.52	59.52	59.52	59.52	1.45	0.29	0.06	0.07	59.52	1261.01	50.33	7.821
$LSD_{\alpha = 0,05}$														
sowing date		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.034	n.s.	n.s.	n.s.	n.s.
harvest date		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.017	n.s.	n.s.	n.s.	n.s.	1.239
interaction		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.034	n.s.	n.s.	n.s.	n.s.	n.s.

* – sowing date: 23.04.; 07.05; harvest date: 01.07; 18.08.; n.s. – not significant

Table 4. Chemical composition as well as pH (in H_2O), EC ($mS \cdot cm^{-1}$) of soil after summer savory cultivation (mean for 2010 and 2011)

Sowing date*	Harvest date*	mg·dm^{-3}								EC	pH
		$N\text{-}NH_4$	$N\text{-}NO_3$	P	K	Ca	Mg	S	Cl		
I	I	15.42	13.22	63.80	93.75	371.75	44.27	23.25	21.25	0.065	5.95
I	II	19.02	18.20	61.50	86.12	455.50	42.42	12.55	7.15	0.057	5.96
Mean for sowing date I		17.22	15.71	62.65	89.93	413.62	43.35	17.90	14.20	0.061	5.95–5.96
II	I	18.87	15.27	66.40	115.50	362.00	51.97	24.95	19.72	0.057	6.00
II	II	15.00	14.37	60.47	71.27	302.75	30.30	11.57	10.05	0.030	6.15
Mean for sowing date II		16.93	14.82	63.43	93.38	332.37	41.13	18.26	14.88	0.043	6.00–6.15
Mean for harvest date	I	17.15	14.25	65.10	104.62	366.87	48.12	24.10	20.48	0.061	5.95–6.00
	II	17.01	16.28	60.98	78.70	379.12	36.36	12.06	8.60	0.043	5.96–6.15
$LSD_{\alpha = 0.05}$											
sowing date		n.s.	n.s.	n.s.	n.s.	47.210	n.s.	n.s.	n.s.	0.016	
harvest date		n.s.	n.s.	1.528	10.045	n.s.	6.065	7.442	6.708	0.016	
interaction		3.854	5.153	2.946	19.371	91.043	11.697	n.s.	n.s.	n.s.	

* – sowing date: 23.04.; 07.05; harvest date: 01.07; 18.08.; n.s.– not significant

antitumor prevention [Ferruzzi and Blakeslee 2007]. The most important properties of carotenoids include their vitamin and antioxidant activities. The total content of these compounds in herbs can vary from 2.0 to 50.0 mg 100 g^{-1} FW [Capecka et al. 2005, Veeru et al. 2009, Daly et al. 2010]. Analyzing the selected parameters of savory yield quality, there was no significant effect of the sowing date on the content of ascorbic acid, chlorophyll a, b, and a + b, as well as carotenoids (tab. 2). Dependencies reported in previous studies conducted under greenhouse conditions were therefore not confirmed [Nurzyńska-Wierdak et al. 2012a, b, c]. This study confirmed the existence of variability factors of chlorophyll [Kadam et al. 2013] and carotenoid pigments [Veeru et al. 2009, Daly et al. 2010]. The highest amount of chlorophyll a, b, a + b and carotenoids were determined in savory from the first sowing date and first harvest date (tab. 2), indicating the environmental variability. Similarly, in previous studies [Nurzyńska-Wierdak et al. 2012b, c] demonstrated that the sowing date significantly affects the chlorophyll content in the fresh herb of different spice species. It should be noted that during drying process of herbal raw materials, chlorophyll content is decreased as a result of thermal degradation [Śledź and Witrowa-Rajchert 2012]. Growing the savory for bunches of fresh herb seems to be therefore a good way to improve the quality of the raw material.

Medicinal and aromatic properties of savory are mainly related to the content and chemical composition of the essential oil. This substance may vary quantitatively and qualitatively under the influence of agronomic factors [Bakkali et al. 2008]. It was shown that the test dates of sowing and harvesting significantly affected the essential oil content in savory herb (tab. 2). More essential oil was found in the herb of plants rather from the first than the second date (respectively 1.76 and 1.64 ml 100 g^{-1} DM), which remained in compliance with previous studies results [Nurzyńska-Wierdak et al. 2012b, c]. Demonstrated relationship may be explained by the strong biochemical reaction (synthesis of essential oil) of oil plants towards climatic conditions, mainly temperature and light. This applies especially to the Mediterranean climate plants, that are particularly sensitive to these factors. The essential oil is best known mixture of active compounds at summer savory. Its concentration ranges from 0.3 to 4.5% and depends largely on the plantation location. Content of essential oil in thyme, savory and other herbal raw materials from Lamiaceae family may be modified by the cultivation system [Seidler-Łożykowska et al. 2006, 2009]. Number of savory oil glands does not increase significantly with the plant development, and majority of glands are present at the stage of very young leaves [Novak et al. 2006]. Harvest of savory bunches can therefore be recommended without any fear of reduction in the aromatic quality of the raw material.

The contents of macro- and microelements in herbs depend on many factors, including the dose and type of fertilization [Dzida 2013, Nurzyńska-Wierdak et al. 2011], soil type, plantation location, as well as cultivated species and its development phase. The mineral economy at studied savory plants changed to a small extent under the influence of studied factors (tab. 3). Significant effect of the sowing date was observed only for the concentration of calcium and chlorine in plants and significant effect of harvest date on the content of calcium, sulfur, and copper in savory herb. Plants during the growing season developed properly. Contents of the main yield-forming factors ranged within optimum limits: 3.5–3.96% d.m. N, 0.36–0.40% d.m. P, 2.36–2.78% d.m. K, which indicates an appropriate plant nutrition. Jadczak and Grzeszczuk [2008], when analyzing the influence of seed sowing date on yield quality of tarragon grown for bunches, recorded similar contents of minerals in studied plants. The harvest of plants largely differentiated the nitrogen and calcium contents in test plants. Raw savory collected in the first date accumulated more amounts of these elements. Similar results were obtained in previous studies with marjoram [Zawiślak and Dzida 2010]. Nitrogen is a nutrient important for plants. After uptake, it plays in plant tissues the role of a substrate in the synthesis of numerous organic compounds: amino acids, proteins, chlorophyll, and phyto- hormones responsible for their development. Both excess and deficiency of nitrogen leads to a biological imbalance, lowering the yield, and its value [Golcz et al. 2002, 2003, Biesiada et al. 2010, Biczak et al. 2011,]. Said-Al Ahl et al. [2009] reported that both at the first and the second harvest, the fresh and dry matter yield of *Origanum vulgare* L. was increased due to $(NH_4)_2SO_4$ fertilization. Among the major dietary components, potassium occupies a unique position in terms of its importance for plant growth and development as it affects directly the water balance within the plant, activates more than 50 enzymes, and increases the plant's resistance to stress. Along with other nutrients, it is one of the conditions for the proper course of metabolic processes in cells, and therefore for achieving the maximum yield [Syers 2005, Isidora et al. 2008]. Potassium acts as a catalyst for a number of enzymatic processes within the plant, which are necessary for its growth. Works of many authors [Smart et al. 1996, Kumar et al. 2006, Lester et al. 2010] underline that the gain of organic matter produced due to photosynthesis, is directly associated with the presence of a proper potassium quantities in nutritional environment of plants. In the absence of potassium, a deterioration of carbon balance occurs in the plant, which is linked to reduction of photosynthesis, while increase of respiration intensity. Another key role of potassium is osmoregulation. K+ ion increases the osmotic potential of a cell, keeping it in turgor and facilitates the penetration of water. In the absence of potassium ions, tissues lose their ability to retain water, and thus increased evaporation takes place along with a decline in yield and increase of transpiration rate. This process influences on the transport of water in xylem, maintenance of cell turgor, their lengthening, and regulates the opening and closing of stomata, which influence on the transpiration and use of carbon dioxide for photosynthesis [Zhao et al. 2001, Szczerba et al. 2009, Boroomand and Sadat 2012].

Another factor differentiating the chemical composition of plants is the type of used shields [Jadczak et al. 2006]. Shields applied in the study (perforated foil and polypropylene woven) caused a decrease of nitrogen, potassium, calcium, and magnesium in basil yield, while did not affect the contents of phosphorus and sodium at plants.

Herbal raw spices can be a valuable source of macro- and micronutrients in the human diet. The contents of macro- and micronutrients varies depending on the origin of raw savory. Seidler-Łożykowska et al. [2007], when analyzing raw savory derived from crops on soils with different chemical composition, found broad limits of the mineral contents in plants. Concentration of most of determined elements in the raw savory from own research was convergent with results of the cited authors.

Herbs are also an excellent source of micronutrients for humans. Examined savory plants contained remarkable amounts of these elements (tab. 3). Savory grown for bunches was characterized by the highest content of iron, that ranged from 880 to

1642 mg kg^{-1} d.m. Besides mint, anise, and rosemary, savory is a plant that accumulate large amounts of microelements, including iron. Regardless of the growing conditions, Seidler-Łożykowska et al. [2008] reported high levels of iron also in marjoram and thyme plants. Zinc, manganese, and copper were present in savory in amounts similar to those reported in the literature [Özcan 2004, Özcan and Akbulut 2007]. Studies involving tarragon performed by Jadczak and Grzeszczuk [2008] revealed the impact of cultivation date on the content of microelements in raw material. Research by Suchorska-Orłowska et al. [2006] shows that the harvesting phase differentiated concentration of microelements in savory herb. Savory was characterized by higher manganese, iron and copper contents, when plants reached the height of 20 cm, while the amount of copper at plants was the highest, when savory was harvested before flowering.

Concentration of macronutrients in soil under savory cultivation indicates that the plants uptook the applied nutrients (tab. 4). Well-nourished plants built-in the absorbed components in the structure of their internal organs. Contents of individual macronutrients in the soil after savory vegetation complete ranged as follows (mg·dm^{-3}): 28.4–37.2 N-min. (N-NH_4 + N-NO_3); 60.5–66.4 P; 71.3–115.5 K; 302.7–455.5 Ca; 30.3–59 Mg; 11.6–25 S-SO_4; 7.2–21.3 Cl. Low concentration of components in the soil caused that the EC value was also low reaching 0.05 mS cm^{-1}. For savory growing, the optimum soil pH is around neutral acidity, while the pH of studied soil was in the slightly acidic range, although it did not adversely affect the plant growth.

CONCLUSIONS

1. Summer savory is suitable for growing for bunches of fresh herb. Given the yield size, the first sowing date (23.04) and the first harvest date of the raw material appeared to be the most favorable.

2. A high biological value of savory herb grown for bunches of fresh herb was shown. The largest amounts of L-ascorbic acid, chlorophyll a, b, a + b, carotenoids, and essential oils were found in plants from the first harvest date. Plants from early sowing date accumulated remarkably more essential oil in the herb than others.

3. Savory herb contained considerable quantities of mineral components, in particular nitrogen, potassium, and calcium. Only the concentration of calcium and sulfur remained significantly influenced by savory sowing date; there were no significant effects of tested parameters on the content of other macronutrients.

4. The content of micronutrients did not change under the influence of agronomic factors studied with the exception of Cu, which depended on the amount of raw materials harvesting time.

5. Analyzing all test parameters affecting the quality of raw material, it is clear that savory plants grown for bunches should be harvested at the beginning of July, regardless of the sowing date.

REFERENCES

Atanassova, M., Georgieva, S., Ivancheva, K. (2011). Total phenolic and total flavonoid contents, antioxidant capacity and biological contaminants in medicinal herbs. J. Univ. Chem. Technol. Metall., 46, 1, 81–88.

Bakkali, F., Averbeck, S., Averbeck, D., Idaomar, M. (2008). Biological effects of essential oils – a review. Food Chem. Toxicol., 46(2), 446–475.

Biczak, R., Herman, B., Rychter, P. (2011). Wpływ nawożenia azotem, fosforem i potasem na plonowanie i wartość biologiczną selera naciowego. Część I: Plon i skład mineralny warzyw. Proc. ECOpole, 5(1), 161–171.

Biesiada, A., Zawirska-Olszańska, A., Kucharska, A., Sokół-Łętowska, A., Kędra, K. (2010). The effect of nitrogen fertilization on nutritive value and antioxidative activity of red cabbage. Acta Sci. Pol. Hortorum Cultus, 9(2), 13–21.

Boroomand, N., Sadat, H.G.M. (2012). Macroelements nutrition (NPK) of medicinal plants: A review. J. Med. Plants Res., 6(12), 2249–2255.

Capecka, E., Mareczek, A., Leja, M. (2005). Antioxidant activity of fresh and dry herbs of some *Lamiaceae* species. Food Chem., 93, 223–226.

Daly, T., Jiwan, M.A., O'Brien, N.M., Aherne, S.A. (2010). Carotenoid content of commonly consumed herbs and assessment of their bioaccessibility using an in vitro digestion model. Plant Foods Hum. Nutr., 65, 164–169.

Dzida, K. (2013). Plon oraz wartość biologiczna ziela tymianku pospolitego (*Tymus vulgaris* L.) i cząbru ogrodowego (*Satureia hortensis* L.) w zależności od żywienia azotem i potasem. Roz. Nauk. 379, UP Lublin.

Farmakopea Polska, VII (2006). Polskie Tow. Farmaceutyczne, Warszawa.

Ferruzzi, M.G., Blakeslee, J. (2007). Digestion, absorption, and cancer preventative activity of dietary chlorophyll derivatives. Nutrit. Res., 27, 1–12.

Golcz, A., Markiewicz, B., Seidler-Łożykowska, K. (2003). Zmiany zawartości składników mineralnych w podłożu i zielu bazylii wonnej (*Ocimum basilicum* L.) w zależności od nawożenia azotem. Rocz. AR Pozn. Ogrodn., 36(348), 15–21.

Golcz, A., Seidler-Łożykowska, K., Markiewicz, B. (2002). Effect of increasing nitrogen doses and harvest terms on the growth and development of sweet basil (*Ocimum basilicum* L.). Part I. Herba Pol., 48, 2, 55–60.

Gontaru, L., Plander, S., Simondi, B. (2008). Investigation of *Satureja hortensis* L. as a possible source of natural antioxidantis. Hungar. J. Ind. Chem. Veszprem, 36 (1–2), 39–42.

Hadian, J., Tabatabaei, S.M.F., Naghavi, M.R., Jamzad, Z., Ramak-Masoumi, T. (2008). Genetic diversity of Iranian accessions of *Satureja hortensis* L. based on horticultural traits and RAPD markers. Sci. Hort., 115, 196–202.

Isidora, R. Pavlovic, M., Sala, F., Adina, B. (2008). Potassium fertilization influence upon vegetables yield quality and soil fertility protection. Res. J. Agric. Sci., 40(2), 147–152.

Jadczak, D. (2007). Effect of sowing date on the quantity and quality of the yield of summer savory (*Satureja hortensis* L.) grown for a bunch harvest. Herba Polon., 53, 3, 22–27.

Jadczak, D., Błaszczuk, A., Rekowska, E. (2006). Effect of covering on the content of macroelements in yield of basil (*Ocimum basilicum* L.) cultivated for a bunch harvest. J. Element., 11(2), 135–141.

Jadczak, D., Grzeszczuk, M. (2008). Effect of sowing date on the quantity and quality of the yield of tarragon (*Artemisia dracunculus* L.) grown for a bunch harvest. J. Elementol., 13(2), 221–226.

Jadczak, D., Grzeszczuk, M. (2009). Effect of sowing date on quantity and quality of yield of chervil (*Anthriscus cerefolium* L. (Hoffm.) ssp. *sativum*) grown for a bunch harvest. Herba Polon., 55, 3, 292–297.

Kadam, V.B., Gaikwad, K.N., Sonawane, V.B., Mali, M.V. (2013). Estimation of chlorophyll content in leaves of some medicinal plants of genus sesbania. J. Drug Discov. Therap., 1(9), 24–26.

Korenman, I.M. (1973). Analiza fitochemiczna. Metody oznaczania związków chemicznych. WN-T, Warszawa, 280–281.

Krężel, J., Kołota, E. (2000). Wpływ odmiany, terminu siewu nasion i osłaniania roślin na plonowanie buraka ćwikłowego na zbiór pęczkowy. Annales UMCS, sec. EEE, Horticultura, suppl., 8 , 219–226.

Kumar, A.R., Kumar, N., Kavino, M. (2006). Role of potassium in fruit crops-a review. Agric. Rev., 27(4), 284–291.

Lester, G.E., Jifon, J.L., Makus, D.J. (2010). Impact of potassium nutrition on food quality of fruits and vegetables: a condensed and concise review of the literature. Better Crops, 94(1), 18–21.

Lichtenthaler, H.K., Wellburn, A.R. (1983). Determinations of total carotenoids and chlorophylls a and b of leaf extracts in different solvents. Biochem. Soc. Trans., 603, 591–592.

Mahboubi, M., Kazempour, N. (2011). Chemical composition and antimicrobial activity of *Satureja hortensis* and *Trachyspermum coptocum* essential oil. Iranian J. Microb., 3, 4, 194–200.

Martyniak-Przybyszewska, B., Majkowska-Gadomska, J. (2006). Wpływ wybranych czynników agrotechnicznych na plon cząbru ogrodowego (*Satureja hortensis* L.) i lebiodki pospolitej (*Origanum vulgare* L.). Annales UMCS, sec. EEE, Horticultura, 16, 113–117.

Martyniak-Przybyszewska, B., Wojciechowski, T. (2004). Plonowanie wybranych gatunków roślin przyprawowych w rejonie Olsztyna. Folia Univ. Agric. Stetin., 239(95), 245–248.

Mulas, M. (2006). Traditional uses of *Labiatae* in the Medditerrenean Area. Acta Hortic., 723, 25–32.

Nojavan, S., Khalilian, F., Kiaie, F.M., Rahimi, A., Arabanian, A., Chalavi, S. (2008). Extraction and quantitative determination of ascorbic acid during different maturity stages of *Rosa canina* L. fruit. J. Food Compos. Analys., 21, 300–305

Novak, J., Bahoo, L., Mitteregger, U., Franz, Ch. (2006). Composition of individual essential oil glands of savory (*Satureja hortensis* L., Lamiaceae) from Syria. Flav. Fragr. J., 21, 731–734.

Nowosielski, O. (1988). Zasady opracowywania zaleceń nawozowych w ogrodnictwie. PWRiL, Warszawa.

Nurzyńska-Wierdak, R., Rożek, E. Borowski, B. (2011). Response of different basil cultivars to nitrogen and potassium fertilization: Total and mineral nitrogen content in herb. Acta Sci. Pol. Hortorum Cultus, 10(4), 217–232.

Nurzyńska-Wierdak, R., Rożek, E., Borowski, B., Dzida, K., Jarosz, Z. (2012a). Changes in the content of some macronutrients in Basil herbage induced by different nitrogen and potassium fertilization rates. J. Elementol., 465–477.

Nurzyńska-Wierdak, R., Rożek, E., Dzida, K., Borowski, B. (2012b). Growth response to nitrogen and potassium fertilization of common basil (*Ocimum basilicum* L.) plants. Acta Sci. Pol. Hortorum Cultus, 11(2), 275–288.

Nurzyńska-Wierdak, R., Rożek, E., Kuźniewska, H. (2012c). Plon i skład chemiczny kolendry siewnej w uprawie szklarniowej. Annales UMCS, sec. EEE, Horticultura, 22(1), 31–38.

Ostrowska, A., Gawliński, S., Szczubiałka, Z. (1991). Metody analizy i oceny właściwości gleb i roślin. Inst. Ochron. Środ., Warszawa.

Özcan, M. (2004). Mineral contents of some plants used as condiments in Turkey. Food Chem., 84, 437–440.

Özcan, M.M, Akbulut, M. (2007). Estimation of minerals, nitrate and nitrite contents of medicinal and aromatic plants used as spices, condiments and herbal tea. Food Chem., 106, 852–858.

Sadeghi, I., Yousefzadi, M., Behmanesh, M., Sharifi, M., Moradi, A. (2013). *In vitro* cytotoxic and antimicrobial activity of essential oil from *Satureja intermedia*. Iran. Red Cres. Med. J., 15(1), 70–74.

Sahin, F., Karaman, I., Gulluce, M., Oguteu, H., Sengul, M., Adiguzel, A., Ozturk, S., Kotan, R. (2003). Evaluation of antimicrobial activities of *Satureja hortensis* L. J. Ethnopharm., 87, 61–65.

Said-Al Ahl, H.A.H., Omer, E.A., Naguib, N.Y. (2009). Effect of water stress and nitrogen fertilizer on herb and essential oil of oregano. Int. Agroph., 23, 269–275.

Seidler-Łożykowska, K., Golcz, A., Kozik, E., Kucharski, W., Mordalski, R., Wójcik, J. (2007). Ocena jakości surowca cząbru ogrodowego (*Satureja hortensis* L.) z uprawy ekologicznej. J. Res. Applic. Agricult. Eng., 52(4), 48–51.

Seidler-Łożykowska, K., Golcz, A., Wójcik, J. (2008). Plonowanie i jakość surowca bazylii pospolitej, cząbru ogrodowego, majeranku ogrodowego oraz tymianku właściwego w uprawie ekologicznej na stanowisku po oborniku. J. Res. Applic. Agricult. Eng., 53(4), 63–66.

Seidler-Łożykowska, K., Kozik, E., Golcz, A., Mieloszyk, E. (2006). Macroelements and essentials oil content in the raw material of the selected medicinal plant species from organic cultivation. J. Res. Applic. Agricult. Eng., 51(2), 161–163.

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 III. Yield and quality of herb and seed yield of summer savory (*Satureja hortensis* L.). Acta Sci. Pol. Agricultura, 8(4), 47–53.

Smart, Ch., Garvin, D., Prince, J., Lucas, W., Kochian, L. (1996). The molecular basis of potassium nutrition in plants. Plant Soil, 187, 81–89.

Solomons, N.W., Ruz, M. (1998). Trace element requirements in humans: an update. J. Trace Elem. Exp. Med., 11, 177–195.

Suchorska-Orłowska, J., Jadczak, D., Brzozowska-Żelechowska, D. (2006). Zawartość niektórych mikroelementów w wybranych gatunkach ziół. Folia Hort., 2, 174–180.

Syers, K.J. (2005). Soil and plant potassium in agriculture a review. Naw. Nawoż., 3(24), 9–36.

Szczerba, M.W., Britto, D.T., Kronzucker, H.J. (2009). K^+ transport in plants: physiology and molecular biology. J. Plant Physiol., 166, 447–466.

Śledź, M., Witrowa-Rajchert, D. (2012). Składniki biologicznie czynne w suszonych ziołach – czy ciągle aktywne? Kosmos. Probl. Nauk Biol., 61, 2(295), 319–329.

Telci, I., Hisil, Y. (2008). Biomass yield and herb essential oil characters at different harvest stages of spring and autumn sown *Coriandrum sativum*. Eur. J. Hortic. Sci., 73, 6, 267–272.

Telesiński, A., Grzeszczuk, M., Jadczak, D., Wysocka, G., Onyszko, M. (2013). Ocena zmian zawartości azotanów (V) w wybranych ziołach przyprawowych w zależności od sposobu ich utrwalania i czasu przechowywania. Żywność. Nauka. Technol. Jakość, 5(90), 168 – 176.

Veeru, P., Kishor, M.P., Meenakshi, M. (2009). Screening of medicinal plant extracts for antioxidant activity. J. Med. Plants Res., 3(8), 608–612.

Wills, R.B.H., Bone, K., Morgan, M. (2000). Herbal products: active constituens, modes of action and quality control. Nitrit. Res. Rev., 13, 47–77.

Zawiślak, G., Dzida, K. (2010). Yield and quality of sweet marjoram herb depending on harvest time. Acta Sci. Pol. Hortorum Cultus, 9(1), 65–72.

Zhao, D., Oosterhuis, D.M., Bednarz, C.W. (2001). Influence of potassium deficiency on photosynthesis, chlorophyll content, and chloroplast ultrastructure of cotton plants. Photosynthetica, 39, 103–109.

Ziombra, M., Frąszczak, B. (2008). Effect of sowing and harvest date on yielding in summer savory (*Satureja hortensis* L.) herbage. Nauka Przyr. Technol., 2, 1, 1–5.

PLON I JAKOŚĆ ZIELA CZĄBRU OGRODOWEGO (*Satureia hortensis* L.) UPRAWIANEGO NA ZBIÓR PĘCZKOWY

Streszczenie. Jakość świeżych ziół wykorzystywanych głównie w celach spożywczych jest zależna od szeregu czynników, w tym środowiskowych i agrotechnicznych. Surowcem farmakopealnym cząbru ogrodowego jest ziele całe lub otarte, które, oprócz olejku eterycznego, zawiera wiele innych związków biologicznie czynnych, m.in. garbniki, karotenoidy, flawonoidy oraz składniki mineralne. Celem badań była ocena plonowania cząbru ogrodowego przeznaczonego na zbiór pęczkowy w zależności od terminu siewu oraz terminu zbioru. Nasiona cząbru wysiano bezpośrednio w pole w dwóch terminach: 23 kwietnia i 7 maja 2010–2011. Surowiec zbierano dwukrotnie: 1 lipca i 16 sierpnia. Zarówno pierwszy termin siewu, jak i pierwszy termin zbioru wpłynęły najkorzystniej na plon świeżego ziela cząbru. Wartość biologiczna otartego ziela była wysoka i zależała od terminu zbioru roślin. Istotnie największą zawartością kwasu L-askorbinowego (39,60 mg 100 g^{-1} św.m.), chlorofilu a + b (88,25 mg 100 g^{-1} św.m.), karotenoidów (26,15 mg 100 g^{-1} św.m.) i olejku eterycznego (1,79 ml 100 g^{-1}) charakteryzowały się rośliny ze zbioru pierwszego. Większą ilością składników pokarmowych odznaczały się rośliny cząbru zebrane w pierwszym terminie w porównaniu do terminu drugiego. Na podstawie otrzymanych wyników wnioskuje się, że możliwe jest zastosowanie suchego ziela cząbru ogrodowego jako źródła biopierwiastków w diecie człowieka. Po przeanalizowaniu wszystkich badanych parametrów wpływających na jakość surowca należy stwierdzić, iż rośliny cząbru przeznaczone na zbiór pęczkowy należy zbierać na początku lipca niezależnie od terminu siewu.

Słowa kluczowe: rośliny lecznicze, termin siewu, termin zbioru, substancje aktywne, makroelementy, mikroelementy

Accepted for print: 7.04.2015

For citation: Dzida, K., Zawiślak, G., Nurzyńska-Wierdak, R., Michałojć, Z., Jarosz, Z., Pitura, K., Karczmarz, K. (2015). Yield and quality of the summer savory herb (*Satureia hortensis* L.) grown for a bunch harvest. Acta Sci. Pol. Hortorum Cultus, 14(3), 141–156.