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VITAMIN AND MINERAL CONTENT IN BLACK CURRANT (*Ribes nigrum* L.) FRUITS AS AFFECTED BY SOIL MANAGEMENT SYSTEM

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ABSTRACT

Black currant contain significant amounts of minerals and vitamins that are associated with an improved health status. The effect of three soil management system (bare fallow, sawdust mulch and black foil mulch) on the content of vitamins and minerals in the fruits of seven black currant cultivars (‘Ben Lomond’, ‘Ben Sarek’, ‘Titania’, ‘Čačanska Crna’, ‘Tisel’, ‘Tiben’ and ‘Tsema’) was analyzed. HPLC-DAD (high performance liquid chromatography-diode array detector) technique was used to define the vitamins A, B_1, B_2 and B_3. Vitamin C were evaluated using a spectrometer, whereas the mineral content of the fruit was determined by flame atomic absorption spectrometry. Significant differences in the minerals and vitamins content were detected among the cultivars. The berries of black currants are rich in mineral composition, especially potassium, phosphours, sodium, calcium and magnesium as well as iron. Also, black currant is an important source of vitamin C and, to a lesser amount vitamins A and B_3. Soil management systems showed highly significant differences in some the tested parameters. Black currants grown on black foil mulch gave the highest levels of K, P and Na, and those on sawdust mulch had a high content of vitamins C, A and B_3. On the other hand, soil management system had no pronounced effect on the other vitamins and minerals analyzed. This study demonstrates degree of differences in the amount vitamins and mineral elements depending on the different soil management systems and climatic factors.

Key words: black currant, vitamins, minerals, soil management system

INTRODUCTION

Fruits and vegetables play an important role in human nutrition and health, particularly as sources of vitamin C, thiamine, niacin, pyridoxine, folic acid, minerals and dietary fibre [Wargovich 2000]. The fruits of black currants provide an inexhaustible source of vitamins which along with minerals make the fruit highly physiologically valuable. Main minerals and essential trace elements are very important in biological processes, and play a vital role in normal growth and development and have also been involved in prevention of some chronic diseases [Gorinstein et al. 2001]. Black currants contain a rich mineral composition which may contribute to health benefits. Analysis of black currant

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constituents reveals that the fruits possess high levels of minerals, especially potassium, calcium, magnesium as well as iron [Lefevre et al. 2011]. Tahvonen [1993] found significant amounts of Ca, Mg, Fe, Mn and Zn in black currant berries, whereas Nour et al. [2011] reported high amounts of potassium, calcium and magnesium but small quantities of sodium. According to Hegedűs et al. [2008], black currants which offer dietary benefits and produce numerous physiological effects in humans have high levels of macroelements (Ca, K, Na, Mg and P), but relatively low concentrations of microelements (Fe, Cu and Zn). Moyer et al. [2002] emphasized that the significant antioxidant capacity of black currant fruits and their processed products is accounted for by a very high content of vitamin C. The high levels of vitamin C and polyphenols contribute to the antioxidant, anti-inflammatory, antimicrobial and anticarcinogenic activities of the fruit [Mazza 2007]. Selection of cultivars and production sites is important for the cultivation of high-quality black currant raw material for health-promoting products [Vagiri et al. 2013].

The most common soil management system used in black currant plantings is bare fallow, but soils are also mulched with organic mulches (sawdust, black plastic, bark, wood chips etc.).

More recently, mulching has been increasingly practised. Numerous studies have highlighted that mulching the soil with sawdust or foil promotes the vegetative and generative potential and has a positive effect on the chemical properties of the fruit [Larsson 1997, Dale 2000, Milivojević et al. 2007, Ochmian et al. 2008].

The aim of the study was to determine the contents of vitamin and mineral elements in fruits of seven black currants cultivars that are cultivated in the different soil management systems.

MATERIALS AND METHODS

Plant material and growth conditions. The research was conducted at the Fruit Research Institute, Čačak, Western Serbia, during 2012–2014 (43°54'N latitude, 20°21'E longitude, 242 m a.s.l.). Three soil management systems were used: treatment I – bare fallow i.e. continuous tillage; treatment II – sawdust mulch, and treatment III – black polyethylene foil mulch. Seven black currant cultivars were included – ‘Ben Lomond’, ‘Ben Sarek’, ‘Titania’, ‘Čačanska Crna’, ‘Tisel’,‘Tiben’ and ‘Tsema’. The experiment was laid out in a randomised block design (7 cultivars × 3 soil management systems × 3 replications × 5 bushes), giving a total of 315 black currant bushes. To obtain comparable samples, berries were selected visually and were at the same stage development and from similar locations in the bushes. Fruits were sampled at full ripeness in June, as during that period of the year these plant parts are fully developed.

Table 1. Mean monthly air temperatures (°C), mean annual air temperatures (A) and mean air temperatures for the vegetative growth period (VG)

Year/ month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	A	VG
2012	1.8	2.5	6.8	12.2	17.3	24.1	26.6	25.4	20.9	13.8	9.5	1.4	13.1	20.0
2013	3.5	3.8	6.6	13.2	18.2	20.6	23.3	24.1	17.2	14.5	8.9	2.0	13.0	18.7
2014	4.0	6.6	10.2	12.8	16.1	21.1	22.7	22.1	17.5	13.5	8.9	3.1	13.2	18.0

Table 2. Average monthly rainfall totals (mm m^{-2}), annual rainfall totals (A) and rainfall totals for the vegetative growth period (VG)

Year/ month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	A	VG
2012	60	70	10	47	68	38	22	0	7.2	30	23.7	87.6	463.5	212.2
2013	51	68	65.7	37	78.5	61.5	10	62.5	87	17.2	40.5	4	582.9	353.7
2014	21.5	6	52.5	104.5	125	103.5	163	56	101	50	19	90	892.0	703.0

Climatic factors. During the experimental period 2012–2014, the average of mean annual air temperatures was 13.1°C, and the average air temperature during the growing season was 18.9°C (tab. 1). The mean annual air temperature was 13.1°C in 2012, 13.0°C in 2013, and 13.2°C in 2014, whereas the mean air temperature during the growing season was 20.0°C, 18.7°C and 18.0°C in respective years. The average amount of rainfall was 646.1 mm m^{-2} for the experimental period, and 422.9 mm m^{-2} for the growing season (tab. 2). Rainfall totals were 463.5 mm m^{-2} in 2012, 582.9 mm m^{-2} in 2013, and 892.0 mm m^{-2} in 2014, whereas the mean amount of rainfall during the growing season was 212.2 mm m^{-2}, 353.7 mm m^{-2} and 703.0 mm m^{-2} in 2012, 2013 and 2014, respectively.

Sample preparation. Fruit samples (10.0 g) were extracted by 96% ethanol (100.0 mL) as a solvent. The extraction process was carried out using an ultrasonic bath (model B-220, Branson Instruments, Smith-Kline Co., Danbury, CT, USA) at room temperature for 1 hour. After filtration, 5 mL of the liquid extract was used for extraction yield determination. The solvent was removed by a rotary evaporator (Devarot, Elektromedicina, Ljubljana, Slovenia) under vacuum and was dried at 30°C to constant weight. The dried extracts were stored in glass bottles at 4°C to prevent oxidative damage until analysis. The analyses of the extracts were carried out immediately after extraction.

Determination of mineral contents. The mineral content of the fruit was determined by flame atomic absorption spectrometry using a Varian Spectar AA 200 instrument equipped with a GTA 110 graphite furnace (Varian, USA). 0.3–0.5 g weighed on a Denver Instruments analytical balance TB-2150 with an accuracy of 0.0001 g in a Teflon cuvette unit for microwave digestion Milestone Ethos TC. The sample was coated with 8 mL of concentrated HNO_3 and 1.5 ml of 30% H_2O_2. Digestion was carried out according to the following temperature program: 5 min–250 W–180°C (temperature in the reference cell) or 65°C (the temperature at the surface of the cuvette measured sensor IC); 5 min–400 W (same temperature criterion); 5 min–500 W (same temperature criterion). After the completion of digestion contents were quantitatively transferred to a volumetric flask of 50 mL and amended to the line deionized water ASTM class I (0,067 uS). Determination of the elements are done by atomic absorption spectrometry flame technique on a Varian SpectrAA 200. With each batch of samples was performed by measuring the absorbance of the calibration standard solution (stock standards are Merck). Calibration of law is constructed from 5 points (including zero) using linear regression. Control samples were blank solutions and solvent blank solutions enriched with a standard solution of the test elements in concentrations that correspond to the second point of the calibration straight line. Each measurement consisted of 3 replicates, during any particular measurement was 3 sec. Determination of phosphorus concentration was carried out by spectrophotometry – Spectrophotometer MA9523-SPEKOL 211 (ISKRA, Horjul, Slovenia) on the basis of specific absorbance of light (725 nm) blue colored phosphor–molybdenum complex. Prepared a series of standard solutions of known concentration in the phosphor was transferred to measuring vessels of 100 ml, and an amount of 0, 1, 2, 3, 4, 5, and 6 ml of the basic standard (concentration 0–6 mg·100 g^{-1}). Of stock solution of the sample in which the concentration of phosphorus was transferred by pipette into 10 ml measuring court of 100 ml. In all measuring vessels (standards and samples) was added to about 50 ml of distilled water, 5 ml of ammonium molybdate solution, 1 ml of sodium sulfite and 1 ml of hydroquinone, and then supplemented with distilled water to 100 ml. Measuring vessels were then sealed, shaken and left in a dark room to develop color during the course of one hour. Upon completion, the spectrophotometer measured the absorbance at 725 nm using a calibration chart and calculated the concentration of phosphorus in mg per 100 g fresh weight of the fruit.

Determination of vitamins. Vitamin C was assessed using a Perkin Elmer UV/VIS spectrometer (Lombda 25). A 50 µl aliquot of the sample solution was mixed with 125 µL of MB (c = 0.4 mmol L^{-1}) solution and diluted to 10 mL with distilled water. The absorbance was measured at 665 nm. A linear relationship was obtained between the decreasing absorbance intensity and the concentration of AA in the concentration range of the analyte between 0.001 mol L^{-1} and 0.05 mol L^{-1}. A high-performance liquid chromatograph (HPLC; Milford, MA, USA) fitted with a fluorescence detector was used for the analysis of vitamins A, B_1, B_2 and B_3 in the fruit samples. The column was Agilent, Eclipse XDB-C18, dimensions (250 × 4.6 mm, 1.8 µm particle size). The mobile phase for vitamins B_1, B_2 and B_3 was water : methanol (CH_3OH) at a ratio of 60 : 40, whereas the mobile phase for vitamin A was water : methanol (CH_3OH) at 5 : 95. Absorption spectra were recorded at the following wavelengths: 247 nm for vitamin B_1, 444 nm for vitamin B_2, 347 nm for vitamin B_3, and 295–330 nm for vitamin A. Results were expressed as milligrams per 100 grams of fresh weight (mg 100 g^{-1}FW).

Statistical analysis. The experimental data obtained during the three-year period were subjected to statistical analysis using Fisher's three-factor analysis of variance – ANOVA. Significant differences between the mean values of the tested factors and the interaction means were determined by LSD test at $P \leq 0.01$ and $P \leq 0.05$ significance levels. The results are presented in tabular and figure form.

RESULTS AND DISCUSSION

Black currants contain minerals and vitamin which are essential to human health. Despite a growing interest in mineral supply from food [Grusak and DellaPenna 1999], only few studies underlined the variability of nutrient accumulation in different berry species**.** The present research is among the few studies that have examined and compared the effect of different soil management systems on the mineral and vitamin content of fruits of black currant cultivars. During the three-year research period, soil management systems had a significant effect on the contents of macroelements K, Na and P, and vitamins C, A and B_3. The contents of vitamins B_1 and B_2 macroelements Ca and Mg, and microelements were highly significantly different across cultivars and years, whereas no differences were observed among treatments. Average content of macro- and micro-mineral nutrients in fruits of black currant are presented in Tables 3 and 4. The fruits of black currant cultivars contained the highest levels of macroelements (Ca, K, Na, Mg and P), which offer dietary benefits and produce numerous physiological effects in humans [Hegedűs et al. 2008]. In our study, 'Ben Sarek' is the cultivar with the highest content of macroelements (K, Na, Ca, P), while 'Ben Lomond' registered higher contents of microelements (Cu, Zn, Se) than the other investigated cultivars. The highest amount was obtained in potassium (330.9–327.1 mg 100 g^{-1}) and the lowest in manganese (0.0035–0.0021 mg 100 g^{-1}) (tab. 3). Also, iron content was higher with variation within 5.29 mg 100 g^{-1} ('Tsema') and 6.36 mg 100 g^{-1} ('Čačanska Crna') (tab. 4). The macro- and microelements, contents could be ranked according

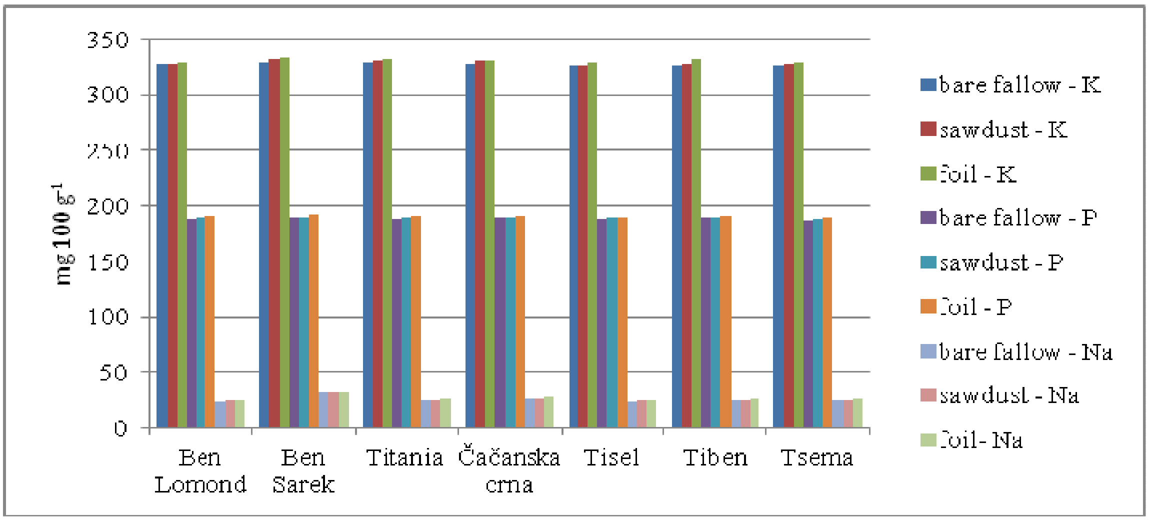

Fig. 1. Relationship between soil management systems and cultivar on minerals K, P and Na

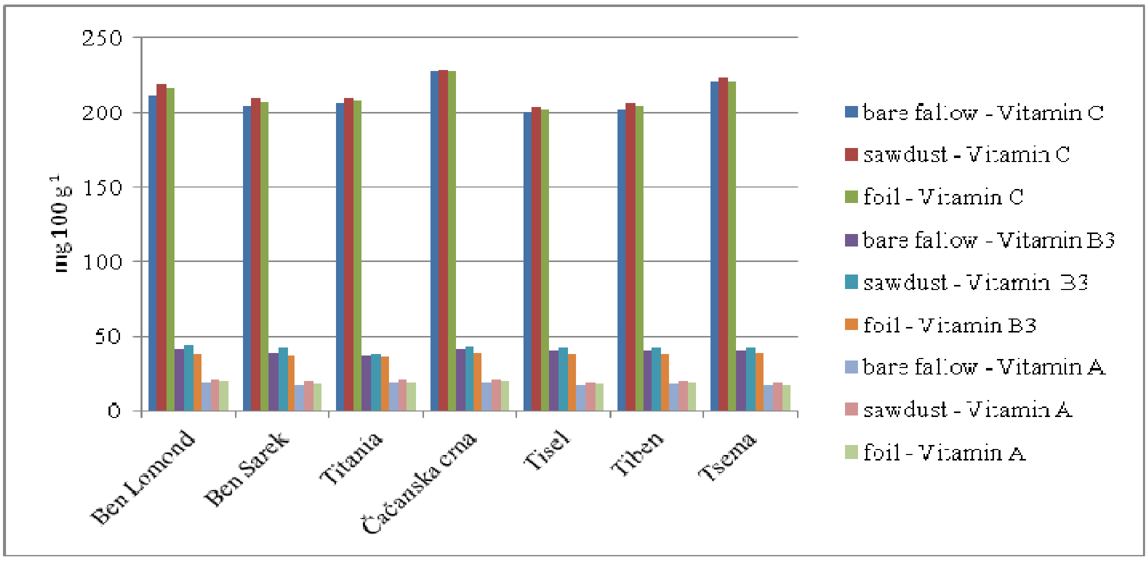

Fig. 2. Relationship between soil management systems and cultivar on vitamins C, B_3 and A

Table 3. Content of macroelements in fruits of black currant cultivars

Cultivar/ Treatment/ Year		K (mg 100 g^{-1})	Na (mg 100 g^{-1})	Ca (mg 100 g^{-1})	Mg (mg 100 g^{-1})	P (mg 100 g^{-1})
Cultivar (A)	‘Ben Lomond’	328.5 ±4.03 de	24.4 ±1.08 ef	30.5 ±0.59 f	27.2 ±0.65 b	189.1 ±1.17 b
	‘Ben Sarek’	331.1 ±3.11 a	31.3 ±1.24 a	38.5 ±0.52 a	28.1 ±0.36 a	190.7 ±1.17 a
	‘Titania’	330.3 ±3.49 ab	25.0 ±1.03 d	31.0 ±0.63 de	27.5 ±0.60 b	189.2 ±0.92 b
	‘Čačanska Crna’	329.8 ±4.03 bc	26.6 ±1.28 b	34.0 ±0.70 b	27.1 ±0.42 b	189.5 ±1.02 b
	‘Tisel’	327.6 ±3.62 e	24.3 ±0.79 f	30.6 ±0.49 ef	26.7 ±0.35 c	188.3 ±0.74 c
	‘Tiben’	329.1 ±3.54 cd	25.5 ±1.11 c	31.7 ±0.56 c	27.2 ±0.23 b	189.6 ±1.12 b
	‘Tsema’	328.0 ±3.98 de	24.8 ±1.19 de	31.4 ±0.50 cd	28.2 ±0.45 a	187.3 ±1.20 d
Treatment (B)	bare fallow	327.7 ±2.35 c	25.4 ±0.77 b	32.5 ±0.50	27.4 ±0.32	187.7 ±0.68 c
	sawdust	328.8 ±2.38 b	25.7 ±0.77 b	32.5 ±0.51	27.4 ±0.29	189.0 ±0.70 b
	foil	331.0 ±2.45 a	26.8 ±0.78 a	32.6 ±0.50	27.5 ±0.29	190.6 ±0.73 a
Year (C)	2012	351.8 ±0.27 a	32.4 ±0.24 a	35.1 ±0.19 a	30.1 ±0.20 a	182.4 ±0.17 c
	2013	329.5 ±0.56 b	23.0 ±0.20 b	32.6 ±0.52 b	27.0 ±0.09 b	189.9 ±0.30 b
	2014	306.3 ±0.49 c	22.6 ±0.85 c	29.8 ±0.48 c	25.1 ±0.14 c	195.1 ±0.24 a
ANOVA						
Cultivar (A)		**	**	**	**	**
Treatment (B)		**	**	ns	ns	**
Year (C)		**	**	**	**	**
A × B		ns	ns	ns	ns	ns
A × C		**	**	**	**	**
B × C		**	ns	ns	ns	ns
A × B × C		ns	ns	ns	ns	ns

Means followed by different letters within the cultivar, treatment and year columns are significantly different at $P \leq 0.01$ and $P \leq 0.05$ according to LSD test and ANOVA (F-test) results

to the following order: K > P > Ca > Mg > Na > Fe > Cu > Zn > Se > Mn. Compared to the present experiment, Perkins-Veazie and Collins [2001] and Hummer and Barney [2002] reported higher values for K and Ca, but significantly lower values for P, Fe and Na, whereas Nour et al. [2011] obtained comparable levels of Ca and Zn, a higher content of Mg, and lower amounts of K, Na and Fe. Cosmulescu et al. [2015] reported a high content of macroelements (K, Mg and Ca) in black currants compared to other soft fruits.

In comparison with other fruits, black currants are low in calories and sodium with significant levels of vitamin A, vitamin B$_1$, vitamin B$_3$, vitamin E, iron, potassium and calcium [Hummer and Barney 2002]. The results on the vitamins content of the fruits are given in Table 5.

Analysing the results for black currant cultivars, significant differences were found for vitamins contents. The highest vitamins levels were measured in ‘Čačanska Crna’ (C, A, B$_1$, B$_2$, B$_3$) and ‘Ben Lomond’ (A, B$_1$, B$_2$, B$_3$), and the lowest in ‘Tisel’ (C, A, B$_1$) and ‘Titania’(B$_2$, B$_3$). The main vitamins in black currant fruit are vitamin C (201.6–228.0 mg 100^{-1}g).

Vitamin C is one of the most important nutritional quality factors in many horticultural crops and has many biological activities in the human body. The content of vitamin C in fruits and vegetables can be influenced by various factors such as genotypic differences, preharvest climatic conditions and cultural practices, maturity and harvesting methods, and postharvest handling procedures [Lee and Kader 2000]. Also, the high concentration of vitamin C in the fruit is also an important marketing tool and an important breeding target [Brennan and Gordon 2002]. Vitamins contents could be ranked according to the fol-

Table 4. Content of microelements in fruits of black currant cultivars

Cultivar/Treatment/Year		Zn (mg 100 g^{-1})	Fe (mg 100 g^{-1})	Cu (mg 100 g^{-1})	Mn (mg 100 g^{-1})	Se (mg 100 g^{-1})
Cultivar (A)	'Ben Lomond'	0.36 ±0.06 a	6.26 ±0.51 a	0.58 ±0.01 a	0.0032 ±0.01 a	0.031 ±0.01 a
	'Ben Sarek'	0.30 ±0.03 e	6.18 ±0.53 a	0.46 ±0.03 e	0.0020 ±0.01 c	0.033 ±0.01 bc
	'Titania'	0.35 ±0.03 b	5.59 ±0.49 c	0.53 ±0.02 c	0.0025 ±0.01 bc	0.028 ±0.01 d
	'Čačanska Crna'	0.29 ±0.01 f	6.36 ±0.53 a	0.55 ±0.02 b	0.0030 ±0.01 ab	0.032 ±0.01 b
	'Tisel'	0.33 ±0.04 c	5.82 ±0.47bc	0.46 ±0.03 e	0.0034 ±0.01 a	0.030 ±0.01 cd
	'Tiben'	0.32 ±0.05 d	5.89 ±0.49 b	0.51 ±0.02 d	0.0035 ±0.01 a	0.034 ±0.01 ab
	'Tsema'	0.30 ±0.03 e	5.29 ±0.39 d	0.44 ±0.03 f	0.0021 ±0.01 c	0.032 ±0.01 b
Treatment (B	bare fallow	0.32 ±0.05	5.96 ±0.33	0.50 ±0.02	0.0027 ±0.01	0.032 ±0.01
	sawdust	0.32 ±0.05	5.93 ±0.33	0.51 ±0.02	0.0027 ±0.01	0.031 ±0.01
	foil	0.32 ±0.05	5.84 ±0.30	0.51 ±0.02	0.0030 ±0.01	0.031 ±0.01
Year (C)	2012	0.36 ±0.06 a	3.67 ±0.04 c	0.68 ±0.01 a	0.0059 ±0.01 a	0.033 ±0.01 a
	2013	0.33 ±0.05 b	4.77 ±0.05 b	0.40 ±0.01 b	0.0020 ±0.01 b	0.034 ±0.01 b
	2014	0.27 ±0.03 c	9.29 ±0.12 a	0.44 ±0.01 c	0.0006 ±0.01 c	0.027 ±0.01 c
ANOVA						
Cultivar (A)		**	**	**	**	**
Treatment (B)		ns	ns	ns	ns	ns
Year (C)		**	**	**	**	**
A × B		ns	ns	ns	ns	ns
A × C		**	**	**	**	ns
B × C		ns	*	ns	*	ns
A × B × C		ns	ns	ns	ns	ns

Means followed by different letters within the cultivar, treatment and year columns are significantly different at $P \leq 0.01$ and $P \leq 0.05$ according to LSD test and ANOVA (F-test) results

lowing order: C > B$_3$ > A > B$_1$ and B$_2$. In Denmark, Pedersen [2008] recorded the highest vitamin C content in 'Čačanska Crna', which is in agreement with the highest values obtained for this cultivar in the present experiment. Nes et al. [2012] in Norway and Zurawicz et al. [2000] in Poland reported higher levels of vitamin C in 'Tisel' and 'Tiben', whereas Siksnianas et al. [2006] in Lithuanian obtained low levels of vitamin C in 'Titania'. Khoo et al. [2012] stressed significant cultivar-dependent variations in vitamin C content. In addition to high levels of vitamin C, Nikolić and Milivojević [2010] reported significant amounts of vitamin B$_1$. Lister et al. [2002] singled out black currants among temperate continental fruit crops as having the highest levels of vitamin C.

The chemical composition of the fruit is governed by the genetic predisposition of cultivar [Bordonaba and Terry 2008] and maturity stage, but also to a large extent by climatic factors [Zheng et al. 2009, Walker et al. 2010, Vagiri et al. 2013]. Climatic conditions including light and average temperature have a strong influence on the chemical composition of crops [Klein and Perry 1982]. Total available heat and the extent of low and high temperatures are the most important factors in determining growth rate and chemical composition of fruits. Across years, the highest content of vitamin C was recorded in 2013, which had more moderate air temperatures and rainfall amounts compared to the other two experimental years. The heavier rainfall and lower air temperatures in 2014 had a positive effect on the synthesis and

Table 5. Vitamin content in fruits of black currant cultivars

Cultivar/ Treatment/ Year		Vitamin C (mg 100 g^{-1})	Vitamin A (mg 100 g^{-1})	Vitamin B_1 (mg 100 g^{-1})	Vitamin B_2 (mg 100 g^{-1})	Vitamin B_3 (mg 100 g^{-1})
Cultivar (A)	‘Ben Lomond’	215.5 ±4.09 c	19.8 ±0.50 a	0.110 ±0.01 a	0.108 ±0.01 a	41.1 ±1.20 a
	‘Ben Sarek’	207.0 ±2.91 d	18.4 ±0.67 d	0.107 ±0.01 a	0.092 ±0.01 c	39.5 ±0.71 c
	‘Titania’	207.7 ±3.46 d	19.5 ±0.66 b	0.087 ±0.01 b	0.083 ±0.01 d	37.6 ±0.42 d
	‘Čačanska Crna’	228.0 ±4.91 a	20.0 ±0.58 a	0.110 ±0.01 a	0.111 ±0.01 a	40.9 ±1.09 a
	‘Tisel’	201.6 ±3.45 f	18.2 ±0.56 d	0.090 ±0.01 b	0.105 ±0.01 b	40.3 ±1.21 b
	‘Tiben’	203.9 ±3.20 e	19.0 ±0.65 c	0.090 ±0.01 b	0.094 ±0.01 c	40.1 ±1.19 b
	‘Tsema’	221.1 ±4.98 b	17.8 ±0.58 e	0.108 ±0.01 ab	0.108 ±0.01 ab	40.3 ±1.20 b
Treatment (B)	bare fallow	210.3 ±2.64 c	18.1 ±0.39 b	0.101 ±0.01	0.101 ±0.01	39.9 ±0.69 b
	sawdust	214.0 ±2.89 a	20.0 ±0.42 a	0.100 ±0.01	0.100 ±0.01	41.8 ±0.69 a
	foil	212.0 ±2.83 b	18.7 ±0.39 b	0.099 ±0.01	0.100 ±0.01	38.2 ±0.68 c
Year (C)	2012	186.7 ±1.09 c	16.4 ±0.23 c	0.049 ±0.01 c	0.044 ±0.01 c	34.8 ±0.13 c
	2013	230.4 ±2.74 a	17.5 ±0.11 b	0.087 ±0.02 b	0.089 ±0.02 b	38.4 ±0.17 b
	2014	219.3 ±0.63 b	23.0 ±0.12 a	0.164 ±0.02 a	0.168 ±0.02 a	46.7 ±0.41 a
ANOVA						
Cultivar (A)		**	**	**	**	**
Treatment (B)		**	**	ns	ns	**
Year (C)		**	**	**	**	**
A × B		ns	ns	ns	ns	ns
A × C		**	**	**	**	**
B × C		**	*	ns	*	ns
A × B × C		ns	ns	ns	ns	ns

Means followed by different letters within the cultivar, treatment and year columns are significantly different at $P \leq 0.01$ and $P \leq 0.05$ according to LSD test and ANOVA (F-test) results

accumulation of vitamins A, B_1, B_2 and B_3, and macroelements P and Fe, whereas the higher air temperature and lower rainfall in 2012 enhanced the synthesis of the other minerals. Lister et al. [2002] determined the dependence of vitamin C content in black currants on production site, with higher levels found in northern countries than in southern countries. Kaldmae et al. [2013] observed that vitamin C content is negatively correlated with temperature, and positively with rainfall, while Walker et al. [2010] found that black currants grown on south facing slopes that received more warmth and solar radiation contained up to 20% more vitamin C than those grown on north facing slopes. Vagiri et al. [2013] reported higher levels of vitamin C in currants grown in the south of Sweden compared to currants grown in the north of Sweden. As explained by the authors, the differences were the result of a higher mean air temperature during harvest season, which was not confirmed in the present study.

CONCLUSION

The present research showed high levels of vitamins and minerals in the analyzed cultivars. Soil management systems and climatic factors have a significant positive effect on the synthesis and accumulation of certain vitamins and minerals, which should be considered when establishing commercial black currant orchards.

Analysing the results for black currant cultivars, significant differences were found for vitamins contents. The highest vitamins levels were measured in 'Čačanska Crna' (C, A, B_1, B_2, B_3) and 'Ben Lomond' (A, B_1, B_2, B_3), and the lowest in 'Tisel' (C, A, B_1) and 'Titania' (B_2, B_3). The main vitamins in black currant fruit are vitamin C (201.6–228.0 mg 100^{-1} g). The macro- and microelements, contents could be ranked according to the following order: K > P > Ca > Mg > Na > Fe > Cu > Zn > Se > Mn.

Generally, the data obtained in this study confirm that black currant represent a valuable source of different vitamins and minerals, and may be considered as a valuable candidate for preparing functional foods.

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