ACTA SCIENTIARUM POLONORUM *Acta Sci. Pol., Hortorum Cultus 12(3) 2013, 69-78*

FERTIGATION OF HIGHBUSH BLEUEBERRY (*Vaccinium corymbosum* L.). PART III. THE EFFECT ON NUTRIENT CONTENTS IN LEAVES

Jacek Glonek, Andrzej Komosa
Poznań University of Life Sciences, Poland

Abstract. Fertigation with the nutrient solutions containing macro and microelements could influence on the nutrient status of highbush blueberry. Studies were conducted in the years 2002–2004 on a 10-year old plantation of highbush blueberry cv. 'Bluecrop'. The aim was to analyze the effect of fertigation using 3 nutrient solutions (F-1, F-2, F-3) in comparison to drip irrigation (F-0) on the contents of macro- and microelements as well as sodium and aluminium in leaves. Fertigation with nutrient solutions F-1, F-2 and F-3 in relation to drip irrigation (F-0) increased the contents of nitrogen, potassium and calcium in the leaves of highbush blueberry cv. 'Bluecrop' at both terms of leaves collection (15.06 and 15.07) while it reduced the content of magnesium with the application of nutrient solutions F-2 and F-3 at the second term of study. No distinct effect of fertigation on the contents of phosphorus and sulphur in leaves was found. Among microelements the greatest effect of fertigation was indicated for boron. Nutrient solutions F-2 and F-3 at the first term as well as F-1, F-2 and F-3 at the second one increased boron content in leaves. Fertigation was found to have an effect on the increase of manganese and copper contents at the term II and zinc at the term I. No variation was recorded in iron content in leaves under the influence of fertigation. Fertigation reduced the content of aluminium in leaves of highbush blueberry. The effect was shown mainly under the influence of the application of nutrient solution F-2. Contents of N, P, K, Zn, Na and B decreased but Ca, Mg, Fe, Mn and Al increased in leaves between the first (15.06) and second II (15.07) term of study. No changes were found in contents of S or Cu in leaves of highbush blueberry at both sampling terms. For the evaluation of highbush blueberry nutrition status in Poland the term II seems to be more advantageous. It is the second half of July, after the first harvest of cv. „Bluecrop". In this period there is the stabilization of vegetative growth with marked effects of bushes yielding.

Key words: nutrient solutions, plant nutrient status, plant analysis, nutrients, aluminium

Corresponding author: Andrzej Komosa, Department of Horticultural Plants Nutrition, University of Life Sciences in Poznań, ul. Zgorzelecka 4, 60-199 Poznań, Poland, tel. (+48) 61 846 63 06, e-mail: ankom@up.poznan.pl

INTRODUCTION

Analyses of leaves have played an important role in the diagnosis of nutrient status of plants. Bailey et al. [1966] indicated a limited effect of nitrogen fertilization on the content of this nutrient in leaves of highbush blueberry. An increase of nitrogen fertilization from 128 to 512 kg $N \cdot ha^{-1}$ was reflected in the upraising of nitrogen content from 1.71 to 1.86% N in d.m. of leaves. Ammonium sulfate is the most popular nitrogen fertilizer using in the cultivation of highbush blueberry because of its acidifying effect on soil [Ball 1997, Finn and Warmund 1997,]. Litten et al. [1997] reported a positive effect of ammonium phosphate, while Percival and Prive [2002] found an advantageous effect of urea on growth and yield of highbush blueberry. Retamales and Hanson [1989] stated that in the yield of highbush blueberry was accumulated 32% nitrogen supplied in urea. Pritts and Hancock [1992] recommended urea fertilization at pH (in H_2O) lower than 5.0 and ammonium sulfate fertilization when pH (in H_2O) is over 5.0. Clark et al. [1998] did not show any effect of the kind of nitrogen fertilization on the nitrogen and other macroelement contents in leaves of highbush blueberry.

The greatest nitrogen requirement is lasting between flowering and fruit ripening [Weinbaum et al.1992]. Throop and Hanson [1997] stated that nitrogen applied in April was by 10% better absorbed by plants than that supplied in May and June. Effectiveness of nitrogen fertigation was greater than spread fertilization.

Townsend [1972], Eaton and Sanderson [1999] did not observe a positive response of highbush blueberry to phosphorus fertilization, while an advantageous effect on growth and yield was shown by Cummings et al. [1971]. An improvement of phosphorus nutrient status as a result of fertilization with this nutrient was reported by Ścibisz et al. [1990].

Cummings [1978] and Eck [1983] showed a positive effect of potassium on nutrient status and yield of highbush blueberry grown in organic soils. A high content of potassium resulted in a reduction of magnesium content in leaves. Potassium content in leaves was maintained at the range of 0.4–0.6% K in d.m.

Nutrient status of highbush blueberry may be assessed on the basis of data presented by Eck [1988] and applied mainly in the USA or estimated by Ball [1998, after Pliszka 2002] and commonly used in The Netherland. Eck [1988] recommended sampling of leaves after the first fruit harvest of cv. 'Bluecrop' (in Poland the second half of July), while Ball [1998, after Pliszka 2002] suggested the second decade of June. Recommended contents of nutrients according to Eck and Ball are as follows (respectively): 1.80–2.10, 2.25–2.75% N, 0.12–040, 0.20–0.30% P, 0.35–0.65, 0.45–0.75% K, 0.40–0.80, 0.40–0.80% Ca, 0.12–0.25, 0.15–0.25% Mg, 0.12–0.20% S (no S by Ball) as well as (in $mg \cdot kg^{-1}$) 60–200, 60–200 Fe, 50–350, 50–350 Mn, 8–30, 10–30 Zn, 5–20, 8–20 Cu, 30–70, 20–50 B d. m. of leaves.

The primary aim of this study was to determine the effect of drip fertigation using different nutrient solutions on contents of nutrients as well as sodium and aluminium in leaves of highbush blueberry.

MATERIALS AND METHODS

Study was conducted in the years 2002–2004 on a 10-year old plantation of highbush blueberry (*Vaccinium corymbosum* L.) cv. 'Bluecrop', established in spring 1992. In the soil with the optimal levels of nutrients which was obtained by the spread fertilization the irrigation and fertigation was applied. The following treatments were tested: F-0 – the control – drip irrigation with water (pH 7.35), F-1 – fertigation with a nutrient solution: 100 mg $N\text{-}NH_4$+$N\text{-}NO_3$, 30 mg $P\text{-}PO_4$, 60 mg K, 30 mg Mg, 0.30 mg B and 0.03 mg $Mo \cdot dm^{-3}$ (pH 5.50, EC 1.10 $mS \cdot cm^{-1}$), F-2 – fertigation with a nutrient solution: 150 mg $N\text{-}NH_4$+$N\text{-}NO_3$, 45 mg $P\text{-}PO_4$, 90 mg K, 45 mg Mg, 0.30 mg B and 0.03 mg $Mo \cdot dm^{-3}$ (pH 5.50, EC 1.45 $mS \cdot cm^{-1}$), and F-3 – fertigation with a nutrient solution: 200 mg $N\text{-}NH_4$+$N\text{-}NO_3$, 60 mg $P\text{-}PO_4$, 120 mg K, 60 mg Mg, 0.30 mg B and 0.03 mg $Mo \cdot dm^{-3}$ (pH 5.50, EC 1.80 $mS \cdot cm^{-1}$). The source of the other nutrients in all nutrient solutions was water from a pond which contained (in $mg \cdot dm^{-3}$): 84.5 Ca, 47.9 $S\text{-}SO_4$, 4.8 Na, 6.6 Cl, 0.160 Fe, 0.054 Mn, 0.041 Zn and 0.009 Cu. Irrigation and drip fertigation were applied in the drought periods in order to maintain free water potential of pF 2.0–2.5. Detailed description of materials and methods was presented in the I and II part of this study [Glonek and Komosa 2012 a, b].

Samples of leaves were collected in two terms – first in the middle of June [Ball 1998, by Pliszka 2002] and second in the middle of July [Eck 1988]. In the first term the 4-th to 6-th fully developed leaves and in the second one the 3-th to 5-th fully developed leaves from the top of annual shoots were taken [Eck 1988]. One average sample consisted of 150–200 leaves from each plot. From one bush were collected 15–20 leaves. The samples were dried and grinded. The mineralization of leaves was done by the following methods: N in sulfuric acid with an addition of sulfosalicilic acid and reduction of $N\text{-}NO_3$ to $N\text{-}NH_4$ with sodium trisulphate and an addition of selenium; P, K, Ca and Mg in sulfuric acid, sulfur – dry mineralization in muffle furnace with HNO_3 and $[Mg(NO_3)_2]$; Fe, Mn, Zn, Cu and Al – in HNO_3, $HClO_4$, H_2SO_4, (100:1:1 v/v); B – dry mineralization with CaO [IUNG 1972]. After mineralization, the following methods were used: N-total – by Kjeldahl; P – colorimetrically with ammonium molybdate; K, Ca, Na – photometrically on flame photometer; Mg, Fe, Mn, Zn and Cu – by atomic absorption spectroscopy (AAS); S – Butters-Chenery method, B – colorimetrically with curcumin [IUNG 1972] and Al – by Jones and Thurman [1957].

The results of nutrients, sodium and aluminium contents in leaves were statistically analyzed by Duncan's multiple range test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

It was found the increase of nitrogen content in leaves of highbush blueberry as the result of fertigation (F-1, F-2, F-3) in comparison to irrigation (F-0). Nitrogen content in leaves was higher at the I term of sampling (15.06) than at the term II (20.07). Evaluating the nutrient status for the term I according to Bal [1997 after Pliszka 2002] it may be stated that irrigated and fertigated bushes showed a low content of nitrogen in leaves (< 2.25% N in d.m.) while at the term II according to Eck [1988] they had an optimal

content (1.80–2.10% N in d.m.). The increase of nitrogen rate in three years of study to 32.67 g N·bush^{-1}·m^{-2} in treatment F-1 in relation to F-0 [Glonek and Komosa 2012a] caused the uprising of nitrogen content at the term I from 1.81 to 1.97% N and 1.68 to 1.80% N in d.m. leaves at the term II (tab. 1). Higher rates of nitrogen (in F-2 at 49.1 g N and F-3 at 65.33 g N·bush^{-1}·m^{-2}) did not increase nitrogen contents in leaves. It is consistent with data reported by Bailey et al. [1966], who recorded a slight increase in the contents of nitrogen in leaves under the influence of high nitrogen fertilization.

Table 1. The effect of fertigation on macroelement contents in leaves (% in d.m.) of highbush blueberry 'Bluecrop' in two terms of study (I, II) in the years 2002–2004

Treatment		2002		2003		2004		$\bar{x}$	
		I	II	I	II	I	II	I	II
N	F-0	1.92 hi	1.84 e-h	1.72 b-d	1.68 bc	1.80 d-f	1.52 a	1.81 b	1.68 a
	F-1	2.17 k	1.90 g-i	1.88 f-i	1.76 c-e	1.86 e-h	1.77 c-f	1.97 d	1.80 b
	F-2	1.98 ij	1.99 ij	1.90 g-i	1.79 c-f	1.89 g-i	1.66 b	1.92 cd	1.81 b
	F-3	2.06 jk	1.89 g-i	1.86 e-h	1.82 d-h	1.80 d-f	1.63 ab	1.91 c	1.77 b
	$\bar{x}$	2.03 b	1.90 a	1.84 b	1.76 a	1.84 b	1.64 a	1.91 b	1.77 a
P	F-0	0.23 c-f	0.20 a-c	0.33 hi	0.16 a	0.33 hi	0.23 c-f	0.30 de	0.20 a
	F-1	0.24 d-f	0.19 a-c	0.31 hi	0.18 ab	0.39 j	0.27 fg	0.31 e	0.21 ab
	F-2	0.23 c-f	0.17 a	0.30 gh	0.22 b-d	0.35 ij	0.31 hi	0.29 cd	0.23 b
	F-3	0.23 c-f	0.18 ab	0.23 c-f	0.20 a-c	0.34 hi	0.26 ef	0.27 c	0.21 ab
	$\bar{x}$	0.23 b	0.18 a	0.29 b	0.19 a	0.35 b	0.27 a	0.29 b	0.21 a
K	F-0	0.66 g	0.58 f	0.38 b	0.27 a	0.47 c	0.42 b	0.50 bc	0.42 a
	F-1	0.64 g	0.57 f	0.41 b	0.40 b	0.53 de	0.48 c	0.53 de	0.48 b
	F-2	0.66 g	0.58 f	0.41 b	0.41 b	0.55 ef	0.53 de	0.54 e	0.51 cd
	F-3	0.63 g	0.57 f	0.41 b	0.50 cd	0.54 d-f	0.56 ef	0.53 de	0.54 e
	$\bar{x}$	0.65 b	0.57 a	0.40 a	0.39 a	0.52 a	0.50 a	0.52 b	0.49 a
Ca	F-0	0.51 c-e	0.70 k-ł	0.38 a	0.62 g-k	0.57 e-i	0.70 k-ł	0.49 ab	0.67 cd
	F-1	0.47 b-d	0.63 h-l	0.41 ab	0.62 g-k	0.54 d-g	0.73 łm	0.47 a	0.66 c
	F-2	0.53 d-f	0.78 m	0.39 ab	0.65 i-ł	0.60 f-j	0.68 j-ł	0.51 b	0.70 de
	F-3	0.53 d-f	0.71 l-m	0.44 a-c	0.70 k-ł	0.56 e-h	0.77 m	0.51 b	0.73 e
	$\bar{x}$	0.51 a	0.70 b	0.40 a	0.65 b	0.57 a	0.72 b	0.49 a	0.69 b
Mg	F-0	0.14 ab	0.16 a-c	0.19 de	0.23 f	0.18 cd	0.21 d-f	0.17 ab	0.20 c
	F-1	0.14 ab	0.16 a-c	0.19 de	0.21 d-f	0.18 cd	0.22 ef	0.17 ab	0.20 bc
	F-2	0.14 ab	0.16 a-c	0.18 cd	0.19 de	0.18 cd	0.19 de	0.17 ab	0.18 b
	F-3	0.13 a	0.15 a-c	0.17 bc	0.17 bc	0.17 bc	0.17 bc	0.16 a	0.16 a
	$\bar{x}$	0.14 a	0.16 b	0.18 a	0.20 b	0.18 a	0.20 b	0.17 a	0.19 b
S	F-0	0.13 c	0.11 a-c	0.10 ab	0.10 ab	0.12 bc	0.12 bc	0.12 a	0.11 a
	F-1	0.13 c	0.12 bc	0.11 a-c	0.10 ab	0.11 bc	0.13 c	0.12 a	0.12 a
	F-2	0.13 c	0.11 a-c	0.11 a-c	0.09 a	0.11 bc	0.13 c	0.12 a	0.11 a
	F-3	0.13 c	0.11 a-c	0.10 ab	0.09 a	0.12 bc	0.12 bc	0.12 a	0.11 a
	$\bar{x}$	0.13 b	0.11 a	0.11 a	0.10 a	0.11 a	0.13 b	0.12 a	0.11 a

Values marked with the same letter did not differ significantly

Similarly as in case of nitrogen, fertigation increased potassium content in leaves, however the response of bushes was smaller than for nitrogen (tab. 1). As a result of the application of nutrient solution F-1 (19.60 g $K \cdot bush^{-1} \cdot m^{-2}$; Glonek and Komosa 2012a) at the term I this content increased from 0.50 to 0.53% K, while at the term II it was from 0.42 to 0.48% K in leaf d.m. An increase in potassium rates (in F-2 at 29.40 g K and F-3 at 39.20 g $K \cdot bush^{-1} \cdot m^{-2}$) resulted in higher contents of potassium in leaves only at the term II. According to Ball [1997] and Eck [1988] both irrigated and fertigated bushes showed optimal potassium contents (0.40–0.80% K in d.m. leaves). Similarly as for nitrogen, the content of potassium at the term II was lower.

There was not clear effect of the fertigation on the phosphorus content in leaves (tab. 1). Content of this nutrient was lower at the second term. The increase of the rates of phosphorus applied in fertigation, amounting in F-1 to 9.80, F.2 to 14.70 and F-3 to 19.60 g $P \cdot bush^{-1} \cdot m^{-2}$ [Glonek and Komosa 2012a], reduced (at the term I for F-3) or increased (at the term II for F-2) the content of phosphorus in leaves. A lack of a marked effect of phosphorus fertilization on phosphorus content in highbush blueberry leaves was shown by Townsend [1972] and Eaton and Sanderson [1999], while a positive effect was stated by Cummings et al. [1971] and Ścibisz et al. [1990]. According to both Bal [1997] and Eck [1988] bushes showed optimal phosphorus nutrition.

Despite the fact that calcium content in the nutrient solutions was identical (water containing 84.5 mg $Ca \cdot dm^{-3}$) the content of calcium in leaves increased as a result of fertigation (tab. 1). This could have been the effect of an increase of calcium contents in soil under the influence of fertigation, particularly marked in the subplough layer [Glonek and Komosa 2012b]. In contrast to N, P, K and Mg, the content of calcium in leaves was higher at the second term of analyses. Nutrient status of bushes was optimal for calcium (0.40–0.80% Ca in leaf d.m.) according to both Bal [1997] and Eck [1988]. Despite of the fact, that highbush blueberry is an acidophilic plant it shows the high content of calcium in leaves. It is necessary to provide adequate calcium nutrition for highbush blueberry, particularly on strongly acid soils – pH (in H_2O) below 4.00.

In spite of the fact that content of magnesium in nutrient solutions increased, which was resulting in an increase in the soil-applied rates (in F-1 to 9.80, F-2 to 14.70 and F-3 to 19.60 g $Mg \cdot bush^{-1} \cdot m^{-2}$; [Glonek and Komosa 2012a]) the content of magnesium in leaves decreased (tab. 1). This effect was indicated particularly at the second term of analyses. It could have been a consequence of K:Mg or Ca:Mg antagonism. A similar effect was stated by Cummings [1978] and Eck [1983]. Magnesium nutrient status of bushes according to Eck [1988] (no data by Ball 1998) was optimal (0.12–0.20% Mg in leaf d.m.).

No effect of fertigation on sulphur content in leaves of highbush blueberry was found (tab. 1). Sulphur content in the nutrient solutions was identical because the source of this nutrient was only water (47.9 mg $S\text{-}SO_4 \cdot dm^{-3}$). No variation in sulphur contents in both sampling terms was noticed. Leaves of highbush blueberry, except for the application of the nutrient solution F-1, showed a low sulphur nutrient status, below of 0.12% S in leaf d.m. [Eck 1988].

Fertigation resulted in an increase of sodium contents in leaves of highbush blueberry, but only at the second sampling term (tab. 2). As a result of applications of nutrient solutions F-2 and F-3 the content of sodium in leaves (in relation to F-0) increased

from 0.04 to 0.07% Na in d.m. of leaves. At the term II the content of sodium was lower. There are no data specifying admissible sodium contents in leaves of highbush blueberry.

Table 2. The effect of fertigation on Na content in leaves (% in d.m.) of highbush blueberry 'Bluecrop' in two terms of study (I, II) in the years 2002–2004

Treatment		2002		2003		2004		$\bar{x}$	
		I	II	I	II	I	II	I	II
Na	F-0	0.07 d-g	0.07 d-g	0.10 g	0.03 a-c	0.08 e-g	0.02 a	0.08 c	0.04 a
	F-1	0.09 fg	0.08 e-g	0.09 fg	0.03 a-c	0.07 d-g	0.04 a-d	0.08 c	0.05 ab
	F-2	0.10 g	0.10 g	0.07 d-g	0.05 b-e	0.07 d-g	0.06 c-f	0.08 c	0.07 bc
	F-3	0.06 c-f	0.09 fg	0.03 a-c	0.05 b-e	0.04 a-d	0.04 a-d	0.05 ab	0.06 a-c
	$\bar{x}$	0.08 a	0.08 a	0.07 b	0.04 a	0.07 b	0.04 a	0.07 b	0.05 a

Note: see Table 1

Table 3. The effect of fertigation on boron and aluminium content in leaves (mg·kg^{-1} d.m.) of highbush blueberry 'Bluecrop' in two terms of study (I, II)

Treatment	B						Al		
	2002		2003		$\bar{x}$		2004		$\bar{x}$
	I	II	I	II	I	II	I	II	
F-0	48.2 d	36.0 a	52.0 e	46.2 cd	50.1 c	41.1 a	194.0 ab	210.8 b	202.4 b
F-1	43.5 b-d	42.5 bc	54.3 ef	48.0 d	48.9 c	45.2 b	163.0 a	222.2 b	192.6 ab
F-2	57.7 fg	38.4 ab	62.9 gh	56.7 ef	60.3 d	47.6 bc	163.5 a	191.1 ab	177.3 a
F-3	57.2 ef	38.4 ab	67.2 h	57.2 ef	62.2 d	47.8 bc	174.0 a	197.9 ab	185.9 ab
$\bar{x}$	51.7 b	38.8 a	59.1 b	52.0 a	55.4 b	45.4 a	173.6 a	205.5 b	-

Note: see Table 1

Enrichment of nutrient solutions with boron up to 0.30 mg B·dm^{-3} resulted in an increase of boron contents in leaves of highbush blueberry (tab. 3). This effect was pointed out at the term I for the nutrient solutions F-2 and F-3 and at the term II for F-1 – F-3. Boron nutrient status was optimal both at the first and second term of leaves collection.

Apart from boron, the effect of fertigation on contents of microelements in leaves was varied (tab. 4). An increase of manganese and copper contents in leaves was indicated at the term II and zinc content at the term I (tab. 4 and 5). In contrast, no effect of fertigation on iron content was shown (tab. 4). It needs to be stressed that contents of these microelements in nutrient solutions were low. Water was their source (0.160 mg Fe, 0.054 mg Mn, 0.041 mg Zn and 0.009 mg Cu·dm^{-3}). Contents of boron and zinc were higher at the term I, while those of iron and manganese at the term II. No changes were

indicated in copper content depending on the leaves term sampling. According to both Ball [1998] and Eck [1988] nutrient status of highbush blueberry was optimal for manganese, low for copper and low or optimal for iron and zinc. Also Domagała-Świątkiewicz and Kolarski [2007] showed a varying evaluation of nutrient status with different varieties of highbush blueberry depending on sampling date. It seems that for Polish conditions the second term of leaves collection is more advisable. It is the second half of July – after the first harvest of cv. 'Bluecrop'. A similar opinion was expressed by Pliszka [2002]. It is the period of stabilization of the vegetative phase, completion of nutrient transport from leaves to fruits [Weinbaum et al. 1992] and the beginning of yielding.

Table 4. The effect of fertigation on Fe and Mn contents in leaves ($mg \cdot kg^{-1}$ d.m.) of highbush blueberry 'Bluecrop' in two terms of study (I, II) in the years 2002–2004

Treatment		2002		2003		2004		$\bar{x}$	
		I	II	I	II	I	II	I	II
Fe	F-0	43.8 a	54.0 d-f	47.8 a-c	53.0 c-f	50.2 cd	60.7 g	47.3 a	55.9 c
	F-1	43.7 a	57.7 fg	49.8 b-d	55.9 e-g	44.2 ab	55.0 d-f	45.9 a	56.2 c
	F-2	51.3 c-e	56.1 e-g	48.0 a-c	55.1 d-g	54.3 d-f	52.7 c-f	51.2 b	54.6 c
	F-3	43.0 a	57.2 fg	43.9 a	52.8 c-f	55.9 e-g	59.5 g	47.6 a	56.6 c
	$\bar{x}$	45.5 a	56.3b	47.3 a	54.2 b	51.2 a	57.0 b	48.0 a	55.8 b
Mn	F-0	101.7 bc	120.1 c-e	96.4 ab	135.7 ef	143.0 f	226.4 h	113.7 b	160.7 c
	F-1	78.0 a	123.8 d-f	140.4 e	229.9 h	121.0 c-e	265.5 i	113.2 b	206.4 e
	F-2	89.3 a	107.6 b-d	100.8 bc	207.4 g	131.4 ef	215.3 gh	107.2 ab	176.8 d
	F-3	78.5 a	128.0 d-f	90. 6 ab	211.8 gh	130.8 ef	231.4 h	100 .0 a	190.4 e
	$\bar{x}$	86.9 a	119.9 b	107.1 a	196.2 b	131.6 a	234.7 b	108.5 a	172.6 b

Note: see Table 1

Table 5. The effect of fertigation on Zn and Cu contents in leaves ($mg \cdot kg^{-1}$ d.m.) of highbush blueberry 'Bluecrop' in two terms of study (I, II) in the years 2002–2004

Treatment		2002		2003		2004		$\bar{x}$	
Zn	F-0	10.9 de	8.0 a	13.7 g	8.9 ab	10.9 de	8.8 ab	11.8 c	8.6 a
	F-1	11.8 ef	8.1 a	12.0 f	8.4 a	10.0 cd	8.5 a	11.2 b	8.3 a
	F-2	12.6 f	8.4 a	12.4 f	8.3 a	10.3 cd	8.8 ab	11.8 c	8.5 a
	F-3	11.8 ef	8.3 a	12.2 f	8.2 a	12.4 f	9.7 bc	12.1 d	8.7 a
	$\bar{x}$	11.8 b	8.2 a	12.6 b	8.5 a	10.9 b	8.9 a	11.7 b	9.2 a
Cu	F-0	4.02 h-j	3.37 d-g	5.16 k	3.64 e-h	2.81 a-c	2.60 ab	4.00 b	3.20 a
	F-1	3.84 g-i	3.88 hi	4.46 j	5.15 k	2.99 b-d	2.70 a-c	3.76 b	3.91 b
	F-2	4.43 j	3.63 e-h	3.68 f-h	4.41 j	3.19 c-f	2.35 a	3.76 b	3.46 a
	F-3	4.33 ij	3.65 e-h	3.75 gh	4.30 ij	3.18 c-e	3.71 gh	3.75 b	3.88 b
	$\bar{x}$	4.15 b	3.63 a	4.26 a	4.37 a	3.04 b	2.84 a	3.82 a	3.61 a

Note: see Table 1

After 3 years of fertigation its effect on aluminium content in leaves of highbush blueberry was searched (tab. 3). Reduced aluminium contents in leaves (in relation to F-0) were particularly evident when applying nutrient solution F-2. No data are available on optimal contents of aluminium in leaves of highbush blueberry. Lockhart and Langille [1962] as standard contents for highbush blueberry reported the range of 73–125 mg Al·kg^{-1} in d.m. of leaves, while Trevett [1972] pointed out 50–75 mg Al·kg^{-1} of leaves d.m. In this study aluminium content in high bush leaves at the term I was 163.0–194.0 mg Al, while at the term II it was 177.3–202.4 mg Al·kg^{-1} of leaves d.m. Although soil aluminium content under the influence of fertigation increased [Glonek and Komosa 2012b] the content of aluminium in leaves decreased. This may be the effect of K:Al, Ca:Al or Mn:Al antagonism. Leaf aluminium content at the term II was similar to the content of manganese, while it considerably exceeded contents of iron and the other microelements.

CONCLUSIONS

1. Fertigation with the nutrient solutions F-1, F-2 and F-3, in relation to drip irrigation (F-0), increased the contents of nitrogen, potassium and calcium in the leaves of highbush blueberry cv. 'Bluecrop' at both terms of leaves collection (15.06 and 15.07) but lowered the content of magnesium at the second term of leaves collection after the application of nutrient solutions F-2 and F-3. No distinct effect of fertigation on the contents of phosphorus and sulphur in leaves was found.

2. Among microelements the greatest effect of fertigation was shown for boron. Nutrient solutions F-2 and F-3 at the first term of leaves sampling as well as F-1, F-2 and F-3 at the second one increased boron content in leaves. Fertigation was found to have an effect on the increase of manganese and copper contents at the term II and zinc at term I. No variation was recorded in iron content in leaves under the influence of fertigation.

3. Fertigation reduced the content of aluminium in leaves of highbush blueberry. The effect was shown mainly under the influence of the application of nutrient solution F-2.

4. It was found the effect of leaves collecting term on the contents of some nutrients as well as sodium and aluminium. Contents of N, P, K, Zn, Na and B decreased between the term I (15.06) and term II (15.07), while contents of Ca, Mg, Fe, Mn and Al increased. No changes were found in contents of S or Cu in leaves of highbush blueberry at both sampling terms.

5. For the evaluation of the nutrient status of highbush blueberry in Poland the term II seems to be more advantageous. It is the second half of July – after the first harvest of cv. „Bluecrop". In this period there is the stabilization of vegetative growth with marked effects of highbush blueberry yielding.

REFERENCES

Bailey J.S., Gersten B., Vlach E., Onalyk G.O., 1966. Response of rubel blueberry bushes to ammonium sulfate and sulfate of potash-magnesia. Proc. Amer. Soc. Hort. Sci. 89, 237–242.

Bal J., 1997. Blueberry culture in greenhouses, tunnels, and under raincovers. Acta Hort. (ISHS) 446, 327–332.

Clark J.M., Naraguma J., Allen A., 1998. Highbush blueberry response to nitrogen rate and method of application: fourth-years result. Res. Series Arkansas. Agri. Exper. Sta. 459, 43–46.

Cummings G.A., 1978. Plant and soil effect of fertilizer and lime applied to highbush blueberries. J. Amer. Soc. Hort. Sci. 103, 302–305.

Cummings G.A., Bickford C., Nelson L., 1971. Fertilizer and lime rate influence highbush blueberry growth and foliar elemental content during establishment. J. Amer. Soc. Hort. Sci. 96, 184–186.

Domagała-Świątkiewicz I., Kolarski K., 2007. Wpływ terminu pobierania próbek do analiz na zawartość składników pokarmowych w liściach czterech odmian borówki wysokiej (*Vaccinium corymbosum* L.). Rocz. Akad. Rol. w Poznaniu. 383, Ogrodnictwo 41, 297–302.

Eaton L.J., Sanderson K.R., 1999. Influence of several rates of phosphorus fertilizer on wild blueberry plants and soil. Can. Soc. for Hortic. Sci. Annual Meeting. Charlottetown, Prince Edward Island.

Eck P., 1983. Optimum potassium nutritional level for production of highbush blueberry. J. Amer. Soc. Hort. Sci. 108, 520–522.

Eck P., 1988. Blueberry science. Rutgers University Press 284, New Brunswick.

Finn C., Warmund M.R., 1997. Fertigation vs. surface application of nitrogen during blueberry plant establishment. Acta Hort. (ISHS) 446, 397–402.

Glonek J., Komosa A., 2012a. Fertigation of highbush blueberry (*Vaccinium corymbosum* L.). Part I. The effect on growth and yield. Acta Sci. Pol., Hortorum Cultus 12(3), 47–57.

Glonek J., Komosa A., 2012b. Fertigation of highbush blueberry (*Vaccinium corymbosum* L.). Part. II. The effect on soil nutrient content. Acta Sci. Pol., Hort. Cultus 12(3), 59–68.

IUNG, 1972. Methods of chemical analyses for the experimental stations of agriculture. Part II. Plant analyses. Inst. Soil Sci. Plant Cult. (IUNG), Puławy (Poland), 25–83.

Jones L.H., Thurman D.A., 1957. The determination of aluminium in soil, ash and plant materials using eriochrome cyanine R.A. Plant and Soil 9(2), 131–141.

Litten W., Smagula J.M., Dunham S., 1997. Blueberry surprise from phosphorus. Maine Agricultural and Forest Experiment Station. The University of Maine, Orono, Maine.

Lockhart C.L., Langille W.M., 1962. The mineral content of the lowbush blueberry. Can. Plant Dis., Survey 42, 124–127.

Percival D.C., Prive J.P., 2002. Nitrogen formulation influences plant nutrition and yield components of lowbush blueberry (*Vaccinium angustifolium* Ait*).* Acta Hort. 574, 347–351.

Pliszka K., 2002. Borówka wysoka. PWRiL, Warszawa.

Pritts M.P., Hancock J.F., 1992. Highbush blueberry production guide. No. 55.

Retamales J.B., Hanson E.J., 1989. Fate of 15N-labeled urea applied to mature highbush blueberries. J. Amer. Soc. Hort. Sci., 114, 920–923.

Ścibisz K., Pliszka K., Cześnik E., Rojek H., 1990. Effect of phosphorus fertilization upon soil P content and P uptake by highbush blueberry (*Vaccinium corymbosum* L.). Acta Hort. (ISHS) 274, 471–480.

Throop P.A., Hanson E.J., 1997. Effect of application date on absorption of N^{15} nitrogen by highbush blueberry. J. Amer. Soc. Hort. Sci. 122, 422–426.

Townsend L.R., 1972. Effect of N, P, K and Mg on the growth and productivity of the highbush blueberry. Can. J. Plant Sci. 53, 161–168.

Trevett M.F., 1972. A second approximation of leaf analysis standard for lowbush blueberry. Research in the life science. Maine Agr. Extp. Sta. 19, 15–16.

Weinbaum S.A., Johnson R.S., Dejong T.M., 1992. Causes and consequences of over fertilization in orchards. Hort. Technology 2, 112–121.

FERTYGACJA BORÓWKI WYSOKIEJ (*Vaccinium corymbosum* L.). CZĘŚĆ III. WPŁYW NA ZAWARTOŚĆ SKŁADNIKÓW POKARMOWYCH W LIŚCIACH

Streszczenie. Fertygacja pożywkami zawierającymi makro i mikroelementy może wpływać na stan odżywienia krzewów borówki wysokiej. Badania przeprowadzono w latach 2002–2004 na 10-letniej plantacji borówki wysokiej odmiany 'Bluecrop'. Badano wpływ fertygacji 3 pożywkami (F-1 – F-3) zawierającymi makro- i mikroelementy, w porównaniu z nawadnianiem kroplowym (F-0), na zawartość makro- i mikroelementów oraz sodu i glinu w liściach. Fertygacja pożywkami F-1, F-2 i F-3 w stosunku do nawadniania kroplowego (F-0) zwiększała zawartość azotu, potasu i wapnia w liściach borówki wysokiej odmiany 'Bluecrop' w obu terminach badań (15.06 i 15.07), natomiast obniżała zawartość magnezu w II terminie przy stosowaniu pożywek F-2 i F-3. Nie stwierdzono wyraźnego wpływu fertygacji na zawartość fosforu i siarki w liściach. Wśród mikroelementów, największy wpływ fertygacji zaznaczył się dla boru. Pożywki F-2 i F-3 w I terminie oraz F-1, F-2 i F-3 w II terminie zwiększały zawartość boru w liściach. Wykazano wpływ fertygacji na wzrost zawartość manganu i miedzi w II terminie oraz cynku w I terminie. Fertygacja nie różnicowała zawartości żelaza, natomiast obniżała zawartość glinu w liściach borówki wysokiej. Efekt ten zaznaczył się głównie pod wpływem stosowania pożywki F-2. Wykazano wpływ terminu pobierania prób na zawartość składników pokarmowych oraz sodu i glinu w liściach borówki wysokiej. Zawartość N, P, K, Zn, Na i B obniżała się między I (15.06) i II terminem (15.07) pobierania prób, natomiast Ca, Mg, Fe, Mn i Al wzrastała. Nie stwierdzono zmian zwartości S i Cu w liściach borówki w dwóch terminach pobierania prób. Dla oceny stanu odżywienia borówki wysokiej w warunkach Polski korzystniejszy wydaje się być termin II, tj. druga połowa lipca – po pierwszym zbiorze odmiany „Bluecrop". Jest to okres stabilizacji wzrostu wegetatywnego z zaznaczonymi efektami plonowania krzewów.

Słowa kluczowe: pożywki, stan odżywienia, analiza roślin, składniki pokarmowe, glin

Accepted for print: 17.10.2012