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FERTIGATION OF HIGHBUSH BLUEBERRY (*Vaccinium corymbosum* L.). PART I. THE EFFECT ON GROWTH AND YIELD

Jacek Glonek, Andrzej Komosa
Poznań University of Life Sciences

Abstract. Fertigation in conjunction with traditional spread fertilization could improve the growth and yield of highbush blueberry. Study was conducted in the years 2002–2004 on a 10-year old plantation of highbush blueberry cv. 'Bluecrop'. The effect of fertigation with 3 nutrient solutions (F-1, F-2, F-3) was investigated in comparison to drip irrigation (F-0) on growth and yield of highbush blueberry. Fertigation with nutrient solution F-1 containing (in mg·dm^{-3}): 100 (N-NH_4+N-NO_3), 30 P-PO_4, 60 K, 30 Mg, 0.30 B and 0.03 Mo, and from the water contents of 84.5 Ca, 47.9 S-SO_4, 4.8 Na, 6.6 Cl, 0.160 Fe, 0.054 Mn, 0.041 Zn and 0.009 Cu (pH 5.50, EC 1.10 mS·cm^{-1}) had a positive effect (in comparison to the drip irrigation) on the fruit yield and single fruit mass of highbush blueberry cv. 'Bluecrop'. An increase of nutrient contents in nutrient solution F-2 to the level of (in mg·dm^{-3}): 150 (N-NH_4+N-NO_3), 45 P-PO_4, 90 K, 45 Mg, 0.30 B and 0.03 Mo (the others as in F-1; pH 5.50 and EC 1.45 mS·cm^{-1}) did not reduce the yield in relation to F-1, while it lowered the mass of one fruit. Yields of highbush blueberry under the influence of drip fertigation in relation to drip irrigation (F-0), at the optimal soil fertility obtained on the basis of spread fertilization, increased as follows: F-1 at 17.3%, F-2 at 21.9% and F-3 at 5.3%. The greatest effect of fertigation on yield of highbush blueberry was found in the year of soil drought, in which the highest rates of nutrient solutions F-1 and F-2 were applied. Fertigation with the nutrient solutions F-1 to F-3 increased dry matter contents of fruits, however it was lower than in drip irrigation. No nitrates or nitrites were detected in fruits of highbush blueberry. Highbush blueberry cv. 'Bluecrop' is a plant with high nutrient requirement. Average yearly nutrient rates for 10–13 years old plantation applied with the treatments F-1 and F-2 (sum of spread fertilization and fertigation) were: 19–24 g N, 10–12 g P, 7–10 g K, 9 g Ca, 6–8 g Mg and 4 g S·m^{-2}·bush^{-1}. For horticultural practice the nutrient solution F-1 could be recommended because of its advantageous effect on yield and the lowest fertilizer expenditure.

Key words: nutrient solutions, spread fertilization, plant nutrition, drip irrigation

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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

Poland ranks first in Europe in terms of cultivation of highbush blueberry (*Vaccinium corymbosum* L.). The cropped area in 2009 was 2400 ha (according to IERiGŻ), while the yield was 11 000 ton (FAO). Great Britain at 1 899 ton and Germany at 100 ton are the main importers of Polish blueberry (2009, according to CAAC and MF). It is estimated that in 2011 area cropped to highbush blueberry increased to 3500 ha and the yield to 17 500 ton.

Plantations of highbush blueberry may be established on medium-heavy and light soils, quality classes III, IV or even V, although enriched with organic matter such as peat moss, sawdust or bark of coniferous trees [Pliszka 2002, Smolarz and Pliszka 2006]. Blueberry in older research papers was classified as a plant with low nutrient requirements [Ballinger 1987, Mainland 1998]. However, recent studies indicate that in comparison to other berry bushes it has high nutrient [Williamson et al. 2006] and water requirements [Perrier et al. 2000, Seymour et al. 2004, Koszański et al. 2005]. For this reason plantations of highbush blueberry should be equipped with drip fertigation systems, preferably with two dripping lines per one row of bushes. Cultivation of highbush blueberries is specific because of their requirement for acidic soils and the prevalence of ericaceous mycorrhizae [Koron and Gogala 2000, Yang et al. 2002, Hanson 2006].

The intensive increase in the production of highbush blueberry in Poland results from the implementation of modern crop nutrition technologies. The primary methods include controlled plant nutrition, based on the knowledge on the abundance of macro- and microelements in the soil, analyses of nutrient status on the basis of leaf analyses as well as a combination of traditional spread fertilization with fertigation [Glonek and Komosa 2004, 2006, Treder et al. 2007]. There are no data on the optimal nutrient solutions for the cultivation of highbush blueberry.

The primary aim of this study was to determine the effect of different nutrient solutions applied in drip fertigation on growth and yield of highbush blueberry cv. 'Bluecrop'.

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 on a commercial plantation in Sarnowo (the Włocławek county). Bushes were planted at a spacing of 3.0 × 0.8 m (4166 bushes·ha^{-1}). The experiment was established on grey-brown podsolic soil – ground gley soil with the A-E_{et}-B_tg-Cg-Dg structure. It was formed by light loamy sands (0–25 cm) and slightly loamy sands (25–62 cm), lying over light loams (62–89 cm). Groundwater was found at a depth of 122 cm (beginning of April), soil quality class IVB.

The topsoil (0–20 cm) showed a low content of available forms of N, P, Mg, Mn, Zn and Cu, adequate pH and EC, while the subsoil horizon had low contents of P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B, adequate pH and low EC (tab. 1). Standard nutrient contents in the soil were maintained by spread fertilization recommended for the cultivation of highbush blueberry (tab. 1); [Komosa 2007].

Table 1. Nutrient and sodium contents before setting up of experiment and nutrient contents maintained in the soil over the years 2002–2004

Nutrient		Before establishment of experiment		During lasting of experiment
		0–20 cm	20–40 cm	0–20 cm
$mg \cdot 100\ g^{-1}$ soil d. m.	$N\text{-}NH_4$	trace	1.1	-
	$N\text{-}NO_3$	trace	1.4	-
	$N\text{-}NH_4+N\text{-}NO_3$	trace	2.5	2.5–5.0
	P	2.6	0.2	3.0–6.0
	K	8.0	2.7	6.0–8.0
	Ca	14.0	8.9	10–30
	Mg	2.2	0.8	3.0–6.0
	$S\text{-}SO_4$	1.3	0.8	1.0–3.0
	Na	1.3	0.8	<5.0
	Cl	1.5	1.4	<5.0
$mg \cdot kg^{-1}$ soil d. m.	Fe	107.8	73.9	75.0–140.0
	Mn	5.4	9.9	20.0–50.0
	Zn	1.4	0.8	3.0–15.0
	Cu	0.8	0.3	1.0–4.0
	B	0.95	0.38	1.0–1.5
pH_{H2O} and EC ($mS \cdot cm^{-1}$)	pH_{H2O}	4.23	4.76	4.20–4.80
	EC	0.17	0.05	<0.35

Apart from spread fertilization, irrigation and drip fertigation were applied. They were used in the periods of soil drought presented in the climograph (fig. 1). In 2002 from July to September drought was observed, marked in low precipitation and high air temperature (the temperature curve lies outside the precipitation one). In 2003 drought was recorded in June, August and September, while in 2004 it was from May to September.

Fertigation was applied using nutrient solutions presented in table 2. The lowest levels of N, P, K and Mg were recorded in nutrient solution F-1, while in nutrient solution F-2 they were by 50% and in F-3 by 100% higher than in F-1. Contents of B and Mo were identical in combinations F-1, F-2, F-3. Ca and $S\text{-}SO_4$ were not used in nutrient solutions due to their high contents in water. Also, the nutrient solutions were not reached in Fe, Mn and Zn because of their adequate levels in the soil. Irrigation and fertigation was applied using water from a pond, characterized by low contents of $N\text{-}NH_4$, $N\text{-}NO_3$, P, K, Mg, Na, Fe, Mn, Zn, Cu and B, high contents of Ca, $S\text{-}SO_4$ and HCO_3, alkaline reaction and medium EC (tab. 2).

Study was conducted for the following treatments: 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·cm^{-1}), F-2 – fertigation with a nutrient solution: 150 mg N-NH_4+N-NO_3, 45 mg P-PO_4, 90 mg K, 45 mg Mg, 0.30 mg B and 0.03 mg Mo·dm^{-3} (pH 5.50, EC 1.45 mS·cm^{-1}), and F-3 – fertigation with a nutrient solution: 200 mg N-NH_4+N-NO_3, 60 mg P-PO_4, 120 mg K, 60 mg Mg, 0.30 mg B and 0.03 mg Mo·dm^{-3} (pH 5.50, EC 1.80 mS·cm^{-1}).

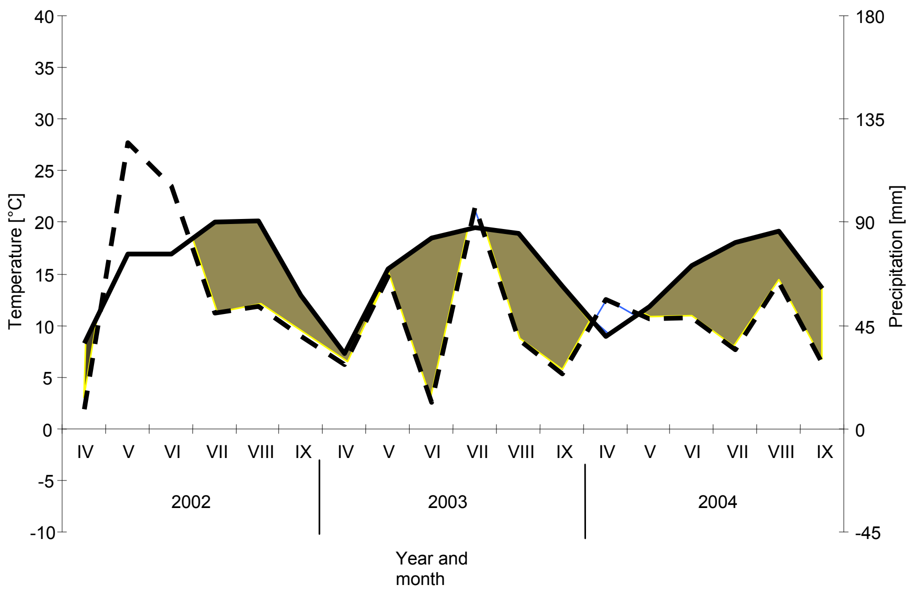

Fig 1. Climograph for the Middle Poland for the years 2002–2004 (broken line – precipitation, solid line – temperature, gray surface – drought)

The nutrient solutions were prepared from the 100-fold concentrated stock solutions and diluted by a Dosatron diluter. Nutrient solutions were transmitted to the bushes by 4 independent systems (F-0 irrigation and F-1 – F-3 fertigation). Nutrient solutions were composed with using: ammonium nitrate (35% N), potassium nitrate (13% N, 38.2% K), magnesium nitrate (11.0% N, 9.5% Mg), monopotassium phosphate (22.3% P, 28.2% K), borax ($Na_2B_4O_7$·10 H_2O, 11.3% B) and sodium molybdate (Na_2MoO_4·$2H_2O$) 39.6% Mo). Total rates of nutrients applied in spread fertilization, irrigation (F-0) and fertigation (F-1, F-2, F-3) in a 3-year study are presented in table 3.

Irrigation and drip fertigation were applied in the drought periods in order to maintain free water potential of pF 2.0–2.5 (-0.01 MPa to -0.03 MPa), which corresponded to soil moisture content of 13.0–17.0%. Free water potential was measured with two tensiometers, placed at a depth of 20 cm along dripping lines (drippers at 22 cm spacing). A single rate of water or nutrient solution for a single plant was 3.3 dm^{-3}·m^{-2}·bush^{-1}. It was supplied by dripping lines, placed at a depth of 5–10 cm (one line per a row of bushes).

In 2002 irrigation and fertigation were applied for 16 days (6 days in May, 4 in June and 6 in July) at 52.8 $dm^3 \cdot m^{-2} \cdot bush^{-1}$ (16 × 3.3 dm^3), in 2003 for 51 days (2 days in May, 23 in June, 16 in July and 10 days in August) using 168.3 $dm^3 \cdot m^{-2} \cdot bush^{-1}$ (51 × 3.3 dm^3), while in 2004 it was 32 days (7 days in June, 14 in July and 11 in August) using 105.6 $dm^3 \cdot m^{-2} \cdot bush^{-1}$ (32 × 3.3 dm^3).

After fertigation, from mid-August each year in drought periods in the F-0 treatment drip irrigation with water was applied (pH 7.37), while in treatments (F-1, F-2, F-3) it was with water acidified (HNO_3) to pH 5.50.

The experiment was established in the systematic design (each treatment with 4 replications in a separate row of plants). A replication comprised a plot of 24 m^2 with 10 bushes. Herbicide fallow was maintained in rows, with sward in the inter rows. The experiment comprised 160 bushes (4 combinations × 4 replications × 10 plants per replication). The border was created by bushes of the commercial plantation.

Soil samples were collected in the middle of March to elaborate recommendation for the fertilization for a given year and in the middle of August to estimate soil fertility at the end of harvest. Soil samples were dried at room temperature, they were ground in a mortar and sifted through a sieve with l mm mesh diameter. The extractions of $N\text{-}NH_4$, $N\text{-}NO_3$, P, K, Ca, Mg, $S\text{-}SO_4$, Na, Cl, and B were carried out in 0.03 M CH_3COOH in a proportion of soil mass:extraction solution = 1:10 [Nowosielski 1974, Komosa and Stafecka 2002]. After extraction, determinations were made according to IUNG (1983): $N\text{-}NH_4$ by microdistillation according to Bremner in the modification by Starck, $N\text{-}NO_3$ by ionoselective electrode ORION, P – colorimetrically with ammonium vanado-molybdate, K, Ca, Mg, Na, – by atomic spectrometry absorption (ASA), $S\text{-}SO_4$ – nephelometrically with $BaCl_2$, Cl – nephelometrically with $AgNO_{3,}$ B – colorimetrically with curcumin.

The microelements – Fe, Mn, Zn and Cu – were extracted with Lindsay solution [Nowosielski 1974, Komosa and Stafecka 2002]. The proportion of soil mass: extraction solution = 1:4. After extraction, Fe, Mn, Zn and Cu were determined by ASA method [IUNG 1983]. Soil pH – potentometically (soil: distilled water 1:2 w/w)and in the same soil solution EC– codumetrically. Water and nutrient solutions were analyzed with the same methods as in the soil. Nitrate and nitrite contents in fruits were determining: with the colorimetric method with α-naphthylamine after the reduction of nitrate to nitrite by cadmium [ISO 1984].

In the course of the experiments the yield of fruit, one fruit weight, the length of 3 longest annual shoots and nitrate or nitrite contents were analyzed. Results of study were statistically analyzed by Duncan's multiple range test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

It was found the coincidence of assumed and chemically determined nutrient contents in the nutrient solutions applied to the plants. (tab. 2). The increasing contents of $N\text{-}NH_4$, $N\text{-}NO_3$, $P\text{-}PO_4$, K and Mg (at constant levels of B and Mo) in nutrient solutions enhanced the natural (originating from water) content of $S\text{-}SO_4$ and Fe, while it reduced Ca content in nutrient solutions. No differences were found in contents of Na, Cl, Mn and Zn between water and nutrient solutions. An increase of the nutrient contents in F-1 to F-3 solutions enhanced their EC from 1.13 to 1.76 mS·cm^{-1}. Moreover, pH was observed to decrease from 5.69 (F-1) to 5.41 (F-3) as a consequence of an increased content of N-NH_4 resulting from increased rates of NH_4NO_3. A reduction of Ca content in nutrient solutions was probably a consequence of an increase in S-SO_4 content and the formation of hard solved $CaSO_4$. An increase in the content of iron could have been the effect of a lowered pH in nutrient solutions. The above mentioned results indicate high accuracy of dilution of 100-fold concentrated nutrient stock solutions by the diluters Dosatron in the tested fertigation systems.

Table 2. Average nutrient and sodium contents in water (F-0) and assumed and determined contents in nutrient solutions F-1, F-2, F-3 (2002–2004)

Nutrient	Water	Assumed nutrient contents			Determined nutrient contents		
	F-0	F-1	F-2	F-3	F-1	F-2	F-3
	mg·dm^{-3}						
N-NH_4	0.7	10	25	41	13.2	15.9	20.2
N-NO_3	1.9	90	125	159	89.2	131.4	189.7
N-NH_4+N-NO_3	2.6	100	150	200	102.2	147.3	209.9
P-PO_4	0.7	30	45	60	27.9	39.8	61.3
K	1.9	60	90	120	60.6	86.9	125.0
Ca	84.5	84.5[a]	84.5[a]	84.5[a]	84.6	76.9	76.1
Mg	15.6	30	45	60	31.4	40.8	61.6
S-SO_4	47.9	47.9[a]	47.9[a]	47.9[a]	47.3	49.2	49.4
Na	4.7	4.8	4.8	4.8	4.8	5.0	5.0
Cl	6.6	6.6	6.6	6.6	6.5	7.4	6.6
Fe	0.160	0.160[b]	0.160[b]	0.160[b]	0.128	0.130	0.155
Mn	0.054	0.054[b]	0.054[b]	0.054[b]	0.061	0.063	0.060
Zn	0.041	0.041[b]	0.041[b]	0.041[b]	0.049	0.051	0.052
B	0.016	0.30	0.30	0.30	0.033	0.035	0.035
Cu	0.009	0.009[b]	0.009[b]	0.009[b]	0.008	0.008	0.008
Mo	śl.	0.03	0.03	0.03	n.o.[c]	n.o.	n.o.
HCO_3^-	290.1	42.7	42.7	42.7	n.o.	n.o.	n.o.
pH	7.37	5.50	5.50	5.50	5.69	5.51	5.41
EC (mS·cm^{-1})	0.74	1.10	1.45	1.80	1.13	1.40	1.76

a – high contents in wate; b – adequate content in soil; n.o. – no determined

Fertigation resulted in an increase of annual shoots (3 longest ones) of highbush blueberry. This effect was pointed out from the second year of the study (2003) (tab. 4). The longest shoots were found in bushes fertigated with nutrient solution F-2, particularly in 2003. It was a dry year, in which the greatest volume of nutrient solution was used (168.3 dm^3·m^{-2}·bush^{-1}).

Table 3. Sum of nutrients and sodium rates applied in the irrigation, spread fertilization and fertigation in 3 years of study (2002–2004)

Nutrient	$g \cdot m^{-2} \cdot bush^{-1}$											
	F-0			F-1			F-2			F-3		
	irrigation	spread fertilization	sum	fertigation	spread fertilization	sum	fertigation	spread fertilization	sum	fertigation	spread fertilization	sum
$N\text{-}NH_4$	0.23	12.24	12.47	3.27	12.24	15.51	8.17	12.24	20.41	13.39	12.24	25.63
$N\text{-}NO_3$	0.62	12.24	12.86	29.40	12.24	41.64	40.84	12.24	53.08	51.94	12.24	64.18
$N\text{-}NH_4$+$N\text{-}NO_3$	0.85	24.48	25.33	32.67	24.48	57.15	49.01	24.48	73.49	65.33	24.48	89.81
$P\text{-}PO_4$	0.23	20.60	20.83	9.80	20.60	30.40	14.70	20.60	35.30	19.60	20.60	40.20
K	0.62	-	0.62	19.60	-	19.60	29.40	-	29.40	39.20	-	39.20
Ca	27.22	-	27.22	27.22	-	27.22	27.22	-	27.22	27.22	-	27.22
Mg	5.09	9.21	14.30	9.80	9.21	19.01	14.70	9.21	23.91	19.60	9.21	28.81
Na	1.57	-	1.57	1.57	-	1.57	1.57	-	1.57	1.57	-	1.57
Cl	2.15	-	2.15	2.15	-	2.15	2.15	-	2.15	2.15	-	2.15
$S\text{-}SO_4$	15.65	12.09	27.74	15.65	12.09	27.74	15.65	12.09	27.74	15.65	12.09	27.74
Fe	0.052	-	0.052	0.052	-	0.052	0.052	-	0.052	0.052	-	0.052
Mn	0.018	-	0.018	0.018	-	0.018	0.018	-	0.018	0.018	-	0.018
Zn	0.013	-	0.013	0.013	-	0.013	0.013	-	0.013	0.013	-	0.013
B	0.0058	0.73	0.7358	0.098	0.73	0.828	0.098	0.73	0.828	0.098	0.73	0.828
Cu	0.0024	-	0.0024	0.0024	-	0.0024	0.0024	-	0.0024	0.0024	-	0.0024
Mo	trace	-	trace	0.0081	-	0.0081	0.0081	-	0.0081	0.0081	-	0.0081

A positive effect of fertigation was observed also in analyses of fruit yield (tab. 4). Similarly as in case of annual shoots, the greatest response to fertigation in blueberry was found in the second year of the study. The best yield was recorded after the application of nutrient solutions F-1 and F-2. Bushes fertigated with F-3 had the reduced yield, although it was similar as when applying drip irrigation F-0. The highest yield was recorded in 2003, characterized by the greatest consumption of water (F-0) and nutrient solutions (F-1 – F-3). The yield of highbush blueberry could be considered as high. An increase in yields as a result of fertigation with nutrient solutions F-1, F-2 and F-3 in relation to drip irrigation F-0 was 17.3, 21.9 and 5.3%, respectively. It needs to be stressed that it is an increase recorded as a result of fertigation applied on soil with optimal nutrient fertility obtained by the traditional spread fertilization which was recommended on the basis of soil chemical analysis. The positive effect of fertigation on yield of blueberry was also shown in studies by Patten [1986], Ben-Porath and Snir [1989], Finn and Warmund [1997] and Treder et al. [2007].

Table 4. The effect of fertigation on the annual shoots length (3 longest) and fruit yield of highbush blueberry cv. 'Bluecrop'

Treatment	Annual shoot length (cm)				Fruit yield ($kg \cdot bush^{-1}$)			
	2002	2003	2004	$\bar{x}$	2002	2003	2004	$\bar{x}$
F-0	85.8 e	92.9 f	72.8 a	83.8 b	4.53 a	7.18 cde	4.67 a	5.46 a
F-1	75.0 b	96.1 g	74.5 b	81.9 a	5.22 ab	8.07 e	5.95 a-c	6.41 bc
F-2	80,8 c	105.9 h	80.2 c	88.9 d	5.56 ab	7.72 de	6.70 b-e	6.66 c
F-3	82.2 d	92.8 f	80.3 c	85.1 c	5.15 ab	6.45 bcd	5.65 a-c	5.75 ab
$\bar{x}$	80.9 b	96.9 c	76.9 a		5.11 a	7.36 b	5.42 a	-

Values marked with the same letter did not differ significantly

Presented study shown that highbush blueberry cv. 'Bluecrop' could be included to the plants with high nutrient requirement. This opinion is in opposition to results of Ballinger [1987] and Mainland [1998], who stated that highbush blueberry has low nutrient requirement. In our study average yearly nutrient rates for 10–13 years old plantation applied with the treatments F-1 and F-2 were (in $g \cdot m^2 \cdot bush^{-1}$): 19–24 N, 10–12 P, 7–10 K, 9 Ca, 6–8 Mg, 4 S (rounded); (tab. 3). This data are in agreement with the study of Williamson et al. [2006].

Fertigation influenced on a fruit weight of highbush blueberry (tab. 5). The greatest weight was recorded for fruits from bushes which were fertigated with nutrient solution F-1. Fruit weight varied in individual years of the study. Similarly as the length of annual shoots and yield, fruit weight was highest in 2003, when nutrient solution consumption was greatest. The variation in yield and quality attributes of fruits in highbush blueberry in different years of cultivation was indicated in the study of Krzewińska et al. [2009].

Table 5. The effect of fertigation on dry mass in fruits and single fruit mass of highbush blueberry cv. 'Bluecrop'

Treatment	Dry mass $\bar{x}$ (%)	Mass of single fruit (g)			
		2002	2003	2004	$\bar{x}$
F-0	16.8 c	1.59 b-d	1.76 c-f	1.31 a	1.55 a
F-1	14.3 a	1.78 ef	2.17 g	1.62 b-e	1.86 b
F-2	15.0 ab	1.50 a-c	1.97 fg	1.39 ab	1.62 a
F-3	16.5 bc	1.51 a-d	1.90 e-g	1.26 a	1.56 a
$\bar{x}$	-	1.59 b	1.95 c	1.40 a	

Note: see Table 4

Dry matter content of fruits collected from fertigated bushes was lower than from irrigated ones (tab. 5). An increase in nutrient contents in nutrient solutions F-1 to F-3 increased dry matter content, leading to a uniformity between combinations F-0 and F-3. The irrigation and fertigation had no effect on nitrate or nitrite contents in fruits. Their contents were on trace levels. It documents that even high nitrogen nutrition which was done in F-1, F-2 and F-3 treatment does not enhance harmful for human mineral forms of nitrogen in fruits.

CONCLUSIONS

1. Fertigation with nutrient solution F-1 containing (in mg·dm^{-3}): 100 (N-NH_4+N-NO_3), 30 P-PO_4, 60 K, 30 Mg, 0.30 B and 0.03 Mo, by the water contents of 84.5 Ca, 47.9 S-SO_4, 4.8 Na, 6.6 Cl, 0.160 Fe, 0.054 Mn, 0.041 Zn and 0.009 Cu (pH 5.50, EC 1.10 mS·cm^{-1}) had a positive effect (in comparison to drip irrigation F-0) on the fruit yield and single fruit mass of highbush blueberry cv. 'Bluecrop'. An increase of nutrient contents in nutrient solution F-2 to the levels of (in mg·dm^{-3}): 150 (N-NH_4+N-NO_3), 45 P-PO_4, 90 K, 45 Mg, 0.30 B and 0.03 Mo (the others as in F-1; pH 5.50 and EC 1.45 mS·cm^{-1}) did not reduce yield in relation to F-1, while it lowered the mass of one fruit.

2. Nutrient solution F-3 containing (in mg·dm^{-3}): 200 (N-NH_4+N-NO_3), 60 P-PO_4, 120 K, 60 Mg, 0.30 B and 0.03 Mo (the others as in F-1; pH 5.50 and EC 1.80 mS·cm^{-1}) reduced yield and one fruit mass.

3. Yields of highbush blueberry cv. 'Bluecrop' under the influence of drip fertigation in relation to drip irrigation (F-0), at the optimal soil fertility obtained on the basis of spread fertilization, increased for: F-1 at 17.3%, F-2 at 21.9% and F-3 at 5.3%.

4. The greatest effect of fertigation on yield of highbush blueberry was found in the year of soil drought, in which the highest rates of nutrient solutions were applied.

5. Fertigation with nutrient solutions F-1 to F-3 increased fruit dry matter contents, however it was lower than in drip irrigation. No nitrates or nitrites were detected in fruits of highbush blueberry.

6. Highbush blueberry cv. 'Bluecrop' is a plant with high nutrient requirement. Average yearly nutrient rates for 10–13 years old plantation with the treatments F-1 and F-2 were (in g·m^2·bush^{-1}: 19–24 N, 10–12 P, 7–10 K, 9 Ca, 6–8 Mg and 4 S.

7. For horticultural practice the nutrient solution F-1 is recommended for the fertigation of highbush blueberry cv. 'Bluecrop', due to its advantageous effect on yield with the lowest fertilizer using.

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FERTYGACJA BORÓWKI WYSOKIEJ (*Vaccinium corymbosum* L.). CZĘŚĆ I. WPŁYW NA WZROST I PLONOWANIE

Streszczenie. Fertygacja w połączeniu z tradycyjnym nawożeniem posypowym może polepszyć wzrost i plonowanie 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) w porównaniu z nawadnianiem kroplowym (F-0) na wzrost i plonowanie borówki wysokiej. Fertygacja pożywką F-1 zawierającą (w $mg \cdot dm^{-3}$): 100 ($N-NH_4+N-NO_3$), 30 $P-PO_4$, 60 K, 30 Mg, 0,30 B i 0,03 Mo, przy zawartości w wodzie 84,5 Ca, 47,9 $S-SO_4$, 4,8 Na, 6,6 Cl, 0,160 Fe, 0,054 Mn, 0,041 Zn i 0,009 Cu (pH 5,50 EC 1.13 $mS \cdot cm^{-1}$) pozytywnie wpływała (w porównaniu z nawadnianiem kroplowym) na masę pojedynczego owocu oraz plon owoców borówki wysokiej odmiany 'Bluecrop'. Wzrost zawartości składników w pożywce F-2 do zawartości (w $mg \cdot dm^{-3}$): 150 ($N-NH_4+N-NO_3$), 45 $P-PO_4$, 90 K, 45 Mg, 0,30 B i 0,03 Mo (pozostałe jak w F-1; pH 5.50 i EC 1.40 $mS \cdot cm^{-1}$) nie obniżał plonu w stosunku do F-1, natomiast zmniejszał masę pojedynczego owocu. Wzrost plonu borówki wysokiej pod wpływem fertygacji kroplowej w stosunku do nawadniania kroplowego (F-0), przy optymalnej zasobności gleby uzyskanej przez nawożenie posypowe, wynosił dla pożywek: F-1 – 17,3%, F-2 – 21,9% i F-3 – 5,3%. Największy wpływ fertygacji na plonowanie borówki wysokiej wystąpił w roku posuchy glebowej, w którym zastosowano największe dawki pożywek. Fertygacja pożywkami F-1 do F-3 zwiększała zawartość suchej masy owoców, jakkolwiek była ona niższa niż w wyniku nawadniania kroplowego. Nie stwierdzono obecności azotanów i azotynów w owocach borówki wysokiej. Borówka wysoka odmiany 'Bluecrop' jest rośliną w wysokich wymaganiach nawozowych. Średnie roczne dawki składników dla 10–13-letniej plantacji w kombinacji F-1 i F-2 (suma nawożenia posypowego i fertygacji) wynosiły: 19–24 g N, 10–12 g P, 7–10 g K, 9 g Ca, 6–8 g Mg i 4 g $S \cdot m^{-2} \cdot krzew^{-1}$. Wydaje się, że dla praktyki ogrodniczej można zalecać pożywkę F-1 ze względu na jej korzystny wpływ na plonowanie i niskie zużycie nawozów.

Słowa kluczowe: pożywki, nawożenie posypowe, żywienie roślin, nawadnianie kroplowe

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