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FERTIGATION OF HIGHBUSH BLEUEBERRY (*Vaccinium corymbosum* L.). PART II. THE EFFECT ON SOIL NUTRIENT CONTENTS

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Abstract. Application of nutrient solutions in fertigation could change chemical properties of soil. Nutrient solutions for highbush blueberry are specific because of characteristic relations among nutrients and acid reaction. Investigations were conducted in the years 2002–2004 on a 10-year old plantation of highbush blueberry cv. 'Bluecrop'. There were searched effects of fertigation using 3 nutrient solutions (F-1, F-2, F-3) contained increased levels of N-NH, N-NO_3, P, K, Mg and constant B and Mo (Ca, S-SO_4, Fe, Mn, Zn, Cu from water) on the contents of nutrients, sodium and aluminium in soil. Fertigation of nutrient solutions F-1, F-2, F-3, in relation to drip irrigation F-0, resulted in the increasing contents of K, Mg, Fe, Mn, Zn and Cu in the plough layer (0–20 cm), while the nutrient solutions F-2 and F-3 upraised the contents of P, S-SO_4 and B. The effect of fertigation on the increase of nutrient contents in the subplough layer (20–40 cm) was pointed out mainly for K and Mg. As a result of fertigation with the highest nutrient contents (F-3) the contents of N-NO_3 increased in the subplough layer. In both layers a tendency to increase of N-NO_3 was noted. Fertigation with nutrient solution F-3 reduced the content of chlorides, while F-2 and F-3 sodium in the plough layer. As a consequence of fertigation with nutrient solutions F-2 and F-3 having pH 5.50 the lowering of soil pH in the plough layer (0–20 cm) was indicated in comparison to drip irrigation (pH of water 7.37). No effect of fertigation was found in the pH of the subplough layer (20–40 cm). As a result of a reduced soil pH the content of aluminium in the plough layer increased. Fertigation with nutrient solutions F-1 to F-3, in relation to drip irrigation F-0, resulted in an increased of EC of the plough and partly in the subplough layer.

Key words: nutrient solutions, macroelements, microelements, soil pH, aluminium

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INTRODUCTION

Yield efficiency of highbush blueberry (*Vaccinium corymbosum* L.) may be significantly increased by the application of controlled plant nutrition with macro- and microelements using traditional spread fertilization in conjunction with drip fertigation. These two fertilization techniques, increasingly often applied in horticultural practice, have resulted in the last four years in a 40% increase in average yields of highbush blueberry in Poland.

Spread fertilization makes the possibility to enhance the contents of macro- and microelements in soil relatively fast (except of phosphorus and boron) while fertigation is a technique maintaining this optimal levels during plant cultivation. The application of drip irrigation alone may result in reduced yield as a consequence of nutrient leaching. Drip fertigation makes it possible to reduce the consumption of fertilizers and optimizes their effectiveness as a result of the possibility to supply nutrients to the root zone [Patten 1986, Treder et al. 2007].

A significant role of fertigation, when applying an acidified nutrient solution, is to reduce or maintain optimal soil reaction. In 1910 Coville showed that optimal soil pH (in H_2O) is 4.3–4.8. Most researchers recorded good plant growth on soils with pH (in H_2O) of 4.0–5.0 [Craig 1967, Johnston et al. 1969]. Lowering of soil pH (in H_2O) to 3.5 caused the reducing of nitrogen content in leaves, resulting in the inhibition of growth and yield [Katakura and Yokomizo 1995]. At such a low soil pH, manganese and aluminium become readily soluble and more toxic to plants, which over a longer period of time leads to their dying [Korcak 1989]. Pliszka [2002] reported pH (in 1 M KCl) of 3.8–4.5 as an optimal acidification level. Williamson et al. [2006] indicated that a satisfactory yield of highbush blueberry was obtained at pH (in H_2O) of 4.2–5.2, while they reported pH (in H_2O) ranging from 4.5 to 4.8 as optimal.

The acid soil reaction as well as the application of an acidified nutrient solution in highbush blueberry plantations causes considerable changes in chemical and microbiological properties of soil. In acid soils availability of all macroelements is reduced, while in case of microelements this tendency is observed for Zn, Cu, B and Mo. In this conditions the intensity of NH^+ and NO_3^- uptake by plant is differentiated [Korcak 1988] and the nitrification process is reduced or it is running more difficult [Hanson et al. 2002].

The aim of this study was to determine the effect of drip fertigation with application of different nutrient solutions contained macro and microelements on changes of nutrient contents as well as sodium and aluminium in soil on the plantation 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 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.

Before establishment of the experiment (3.04.2002) the plough layer (0–20 cm) and the subplough layer (20–40 cm) acquired the following nutrient contents (in mg·100 g^{-1} d.m. soil, respectively): N-NH_4 traces (tr.), 1.1, N-NO_3 tr., 1.4, P 2.6, 0.2, K 8.0, 2.7, Ca 14.0, 8.9, Mg 2.2, 0.8, S-SO_4 1.3, 0.8, Cl 1.5, 1.4, and (in mg·kg^{-1} d. m.) Na 13.0, 8.0, Cl 15.0, 14.1, Fe 107.8, 73.9, Mn 5.4, 9.9, Zn 1.4, 0.8, Cu 0.8, 0.3, B 0.95, 0.38 and pH (in H_2O) 4.23, 4.76, EC 0.17, 0.05 mS·cm^{-1}. Optimal nutrient contents in soil in all combinations (F-0, F-1, F-2, F-3) was obtained by the spread fertilization applied from mid-March to mid-May, maintaining nutrient levels within the range of guide values (in mg·100 g^{-1} d.m. soil): N-NH_4+N-NO_3 2.5–5.0, P 3.0–6.0, K 6.0–8.0, Ca 10.0–30.0, Mg 3.0–6.0, S-SO_4 1.0–3.0 and (in mg·kg^{-1} d.m.) Na < 50.0, Cl < 50, Fe 75.0–140.0, Mn 20.0–50.0, Zn 3.0–15.0, Cu 1.0–4.0, B 1.0–1.5; pH (in H_2O) 4.00–5.00, EC up to 0.35 mS·cm^{-1} in the layers of 0–20 and 20–40 cm [Komosa 2007].

On the optimal soil fertility drip irrigation and drip fertigation were applied testing the following treatments: F-0 – the control – drip irrigation with water (pH 7.35), F-1 – fertigation with nutrient solution: 100 mg N-NH_4+N-NO_3, 30 mg P-PO_4, 60 mg K, 30 mg Mg, 0.30 mg B and 0.03 mg Mo·dm^{-3} (pH 5.50), F-2 – fertigation with 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) and F-3 – fertigation with 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). Water was the source of the other nutrients in all nutrient solutions and it contained (in mg·dm^{-3}): 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. Irrigation and fertigation were applied using water from the pond. Detailed results of analyses of nutrient contents in water, nutrient solutions and soil were presented in part I of this study [Glonek and Komosa 2012].

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 taken by a soil sampler from the depth of 0–20 cm and a soil drill from the depth of 20–40 cm in the radius of 20 cm from the drippers. Analyses of soil were made according to the universal method. The extraction of N-NH_4, N-NO_3, P, K, Ca, Mg, S-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].

The microelements – Fe, Mn, Zn and Cu – were extracted with Lindsay solution [Nowosielski 1974, Komosa and Stafecka 2002], by the soil mass: extraction solution 1:4 ratio (w/w). Aluminium (Al) was determined according to Grewling-Peech [Nowosielski 1974], pH – potentometically (soil: distilled water 1:2 w/w) and in the same soil solution EC- codumetrically. Particular description method of soil analyses was presented in part I [Glonek and Komosa 2012]. Results of study were statistically analyzed by Duncan's multiple range test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Drip fertigation with nutrient solutions F-1, F-2 and F-3 acidified to pH 5.50 in relation to drip irrigation with water at pH 7.37 reduced pH of soil in the plough layer (0–20 cm) from 4.95 to 4.53 (tab. 1). This was accompanied with an increase of aluminium content, which is typical for acid soils. A similar effect on plantations of highbush blueberry was reported by Korcak [1988]. In contrast, no acidifying effect of nutrient solutions was found in the subplough layer (20–40 cm), however a marked trend for a reduction of pH was observed. The lowest pH in the subplough layer, amounting to 4.57, caused by the application of nutrient solution F-2 significantly increased aluminium content (50.2 mg $Al \cdot kg^{-1}$ d.m. soil) (tab. 1). Highbush blueberry shows high tolerance to aluminium [Reyes-Diaz et al. 2011].

Table 1. The effect of fertigation on pH and EC and contents of aluminium in soil layers of 0–20 and 20–40 cm (means of 2002–2004)

Treatment		Al ($mg \cdot kg^{-1}$ soil d.m.)	pH (in H_2O)	EC ($mS \cdot cm^{-1}$)
Layer of 0–20 cm	F-0	26.2 a	4.95 b	0.15 a
	F-1	42.3 b	4.62 ab	0.23 b
	F-2	47.2 b	4.53 a	0.22 b
	F-3	38.4 b	4.55 a	0.25 b
Layer of 20–40 cm	F-0	43.3 ab	4.70 a	0.16 a
	F-1	36.0 a	4.61 a	0.23 b
	F-2	50.2 b	4.57 a	0.20 a
	F-3	35.6 a	4.81 a	0.17 a

Values marked with the same letter within a soil layer did not differ significantly

Increasing nitrogen content in nutrient solutions F-1 to F-3 did not increase contents of $N\text{-}NH_4$ and $N\text{-}NO_3$ in the *plough layer* (0–20 cm) of soil (tab. 2), while it increased contents of $N\text{-}NO_3$ in the *subplough layer* (20–40 cm). This was particularly evident at the highest nutrient solution concentration (F-3). Analyses documented the translocation of $N\text{-}NO_3$ from the plough to subplough layer. A tendency was also observed for an increase in the contents of mineral nitrogen ($N\text{-}NH_4$ and $N\text{-}NO_3$) in both soil layers as a result of higher nitrogen concentrations applied in nutrient solutions (F-2 and F-3). A low pH of soil plantation of highbush blueberry stimulates the process of NO_3^- translocation to the deeper layers of the soil.

It was found that the content of $N\text{-}NH_4$ was higher than $N\text{-}NO_3$ in both soil layers. This is a typical state for strongly acid soils. The NH_4^+ ion, in contrast to NO_3^-, is absorbed by the sorption complex. Townsend [1967] and Korcak [1988] reported that highbush blueberry absorbed the NH_4^+ form in greater amounts than NO_3^-. However, some studies do not confirm this opinion [Hammett and Ballinger 1972, Takamizo and Sugiyama 1991]. According to Paterson et al. [1988] and Merhaut and Darnell [1995], the uptake of NH^+ by highbush blueberry is higher when the NH_4^+ form is in balance with NO_3^- in the root medium.

Natural environment of highbush blueberry growth are acid and low fertility soils. Under such conditions most inorganic nitrogen available for plants is found in the ammonium form as long as the activity of nitrifying bacteria is not stimulated [Dancer et al. 1973]. Intensity of nitrification increases with the age of plants. It is higher in old plantations than in the surrounding forest soils [Hanson et al. 2002]. A higher nitrification capacity is found in lowbush blueberry than in highbush blueberry [Eaton and Patriquin 1988]. Intensity of nitrification is not only dependent on soil pH, but also on contents of NH_4^+, the kind of applied fertilizers, oxygen contents and soil structure [Hanson 2006].

Fertigation with nutrient solutions F-2 and F-3 resulted in an increased phosphorus content in the plough layer, while in case of nutrient solution F-3 it was also in the subplough one (tab. 2). This indicates the translocation of mineral phosphorus in soils enriched with organic matter (sawdust mulching) on plantations of highbush blueberry despite of the fact that phosphorus is a nutrient with low mobility in the soil. An increase in phosphorus content in soil on the highbush blueberry plantation under the influence of spread fertilization was shown by Ścibisz et al. [1990].

Table 2. The effect of fertigation on macronutrient contents in soil layers of 0–20 and 20–40 cm (means of 2002–2004)

Treatment		$N-NH_4$	$N-NO_3$	$N-NH_4+$ $N-NO_3$	P	K	Ca	Mg	$S-SO_4$
Layer of 0–20 cm ($mg \cdot kg^{-1}$ soil d. m.)	F-0	1.24 a	0.82 a	2.14 a	4.43 a	6.50 a	30.8 ab	4.30 a	4.76 a
	F-1	1.16 a	0.69 a	1.85 a	4.95 ab	8.66 b	29.2 a	5.33 b	6.04 ab
	F-2	1.53 a	0.97 a	2.51 a	5.12 b	9.62 b	29.1 a	5.32 b	7.05 b
	F-3	1.19 a	1.33 a	2.53 a	5.49 b	8.81 b	32.3 b	6.23 c	9.65 c
Layer of 20–40 cm ($mg \cdot kg^{-1}$ soil d. m.)	F-0	1.13 a	0.71 a	1.83 a	2.09 b	4.97 a	23.2 a	14.38 a	8.12 a
	F-1	1.21 a	0.95 ab	2.16 a	1.53 a	6.67 c	30.6 b	21.28 c	7.69 a
	F-2	1.63 a	1.18 ab	2.80 a	2.01 ab	6.04 b	27.8 ab	15.60 a	6.33 a
	F-3	1.25 a	1.24 b	2.49 a	2.78 c	5.90 b	25.2 a	18.31 b	6.68 a

Note: see Table 1

Fertigation strongly increased potassium content both in the plough and subplough layers (tab. 2). This effect was indicated already at the application of the nutrient solution with the lowest nutrient contents (F-1). Presented results pointed out the high efficiency of elevated potassium abundance of soil as a result of fertigation. Similarly as in case of potassium, fertigation resulted in an increased magnesium content, with the increase being much greater in the subplough layer (20–40 cm) (tab. 2).

No marked changes were found in calcium contents in soil under the influence of fertigation (tab. 2). Water was the source of calcium in the nutrient solutions, as it contained high amounts of the readily available (ionic) form of this nutrient (84.5 Ca·dm^{-3}). A lack of marked changes in calcium contents may be connected with the high contents of this nutrient in soil, despite it being strongly acid. Facteau and Eck [1970] and Townsend [1972] showed that saturation of the sorption complex with basic cations of Ca, Mg, K and Na above 22–35% reduces growth of highbush blueberry.

Although sulfate fertilizers were not applied in nutrient solutions (sulfates originated from water at 47.9 S-SO_4·dm^{-3}), the content of these anions in the 0–20 cm soil layer increased under the influence of fertigation with nutrient solutions F-2 and F-3 (tab. 2). In contrast, no differences were found in the 20–40 cm layer. This was probably a consequence of the more intensive chemical sorption of SO_4^{--} by Ca^{2+} ions and the formation of hard soluble $CaSO_4$ in the upper soil layer, being more abundant in calcium, than by lower one. Komosa [2007] pointed out that 55% soils in highbush blueberry plantations in Poland shown an insufficient sulfur content, while 21% soils had excessive levels. This was connected with soil sulphurization performed in order to lowering pH.

Fertigation with nutrient solutions F-1, F-2, F-3 increased iron content in the plough layer, while it did not cause marked changes in the subplough layer (tab. 2). Iron in nutrient solutions originated from water (0.160 mg Fe·dm^{-3}). An increase in iron content in soil may have resulted from a decrease in pH as a consequence of fertigation (tab. 1).

The contents of manganese and zinc in the plough layer increased markedly as a result of fertigation (tab. 2). This was mainly a consequence of soil acidification, and not the contents of these microelements in the nutrient solutions, as they were low. Water was the source of manganese and zinc (0.054 mg Mn and 0.041 mg Zn·dm^{-3}). The effect of fertigation on an increase in the contents of zinc and manganese was also shown in the subplough layer, although it was much lower.

Similarly as in case of iron, manganese and zinc, fertigation increased the contents of copper and boron (tab. 3). This increase was particularly evident in the upper layer (0–20 cm) of soil when nutrient solutions F-2 and F-3 were applied, while in the lower layer (20–40 cm) it was for nutrient solution F-3 and only for copper. Water was the source of copper (0.009 mg Cu·dm^{-3}), while boron was added to nutrient solutions (0.30 mg B·dm^{-3}). A study by Komosa [2007] showed that only 3% examined highbush blueberry plantations in Poland had low contents of iron, while it was 14% for zinc, 24% boron, 28% copper and 54% manganese.

In contrast to the examined microelements, under the influence of fertigation the content of chlorides in the 0–20 cm soil layer decreased; significant effect was shown on F-3 treatment (tab. 3). This was mainly a consequence of the application of nutrient solutions with high nutrient contents (F-2 and F-3) and stimulation of Cl^- ion leaching at a decreasing pH of soil. In turn, no changes were observed in chloride contents in the subplough layer. Chloride contents in nutrient solutions were low. They only originated from water (6.6 mg Cl·dm^{-3}). Specific nutrient contents in water and nutrient solutions were presented in part I of the study [Glonek and Komosa 2012].

Table 3. The effect of fertigation on micronutrient and sodium contents in soil layers of 0–20 and 20–40 cm (means of 2002–2004)

Treatment		Fe	Mn	Zn	Cu	B	Cl	Na
Layer of 0–20 cm ($mg \cdot kg^{-1}$ soil d. m.)	F-0	113.6 a	17.5 a	14.0 a	1.89 a	1.25 a	24.9 b	43.6 c
	F-1	130.3 b	27.9 bc	22.2 c	2.47 b	1.37 ab	23.8 b	39.3 bc
	F-2	126.0 b	24.4 b	18.7 b	2.36 ab	1.42 b	21.1 ab	33.9 ab
	F-3	127.8 b	29.4 c	17.9 b	3.26 c	1.51 b	18.9 a	33.3 a
Layer of 20–40 cm ($mg \cdot kg^{-1}$ soil d. m.)	F-0	117.7 ab	13.1 a	3.3 a	0.96 a	1.27 b	17.4 a	42.6 b
	F-1	119.8 ab	26.7 b	5.1 c	1.13 a	1.23 b	20.1 a	57.9 c
	F-2	122.4 b	16.3 a	3.8 ab	0.96 a	1.11 b	18.3 a	42.7 b
	F-3	114.2 a	15.1 a	4.4 b	1.42 b	0.85 a	18.8 a	35.5 a

Note: see Table 1

Similarly as in case of chlorides, under the influence of fertigation with nutrient solutions F-2 and F-3 the content of sodium decreased in the plough layer (tab. 3). In the subplough layer sodium content increased only on the F-1 treatment, but significant decreased under the influence of nutrient solution F-3. Sodium content in nutrient solutions was very low and was originated only from water (4.7 mg $Na \cdot dm^{-3}$). A reduction of sodium content may have been a consequence of the displacement of sodium from the sorption complex by NH_4^+, K^+, Mg^{2+} and Ca^{2+} cations in nutrient solutions and its being leached to deeper soil layers.

The EC value increased as a consequence of increased contents of P, K, Mg, S-SO_4 and Al (partly N-NH_4+N-NO_3) in the soil under the influence of fertigation (tab. 1). This effect was also marked in the subplough layer, particularly when nutrient solution F-1 was applied. However, the admissible salinity level, amounting to 0.35 $mS \cdot cm^{-1}$, was not exceeded [Komosa 2007]. According to that author, guide values for the plough and subplough layers are (in $mg \cdot 100\ g^{-1}$ d.m. soil): N-NH_4+N-NO_3 2.5–5.0, P 3.0–6.0, K 6.0–8.0, Ca 10.0–30.0, Mg 3.0–6.0, S-SO_4 1.0–3.0 and (in $mg \cdot kg^{-1}$ d.m.) Na < 50.0, Cl < 50, Fe 75.0–140.0, Mn 20.0–50.0, Zn 3.0–15.0, Cu 1.0–4.0 and B 1.0–1.5. When comparing the results of this study with these guide values it may be stated that the plough layer in the highbush blueberry plantation, on which spread fertilization combined with fertigation was applied for 3 years, had low or optimal content of N-NH_4+N-NO_3, optimal contents of P, Mg, Fe, Mn, Cu, B, Na and Cl, optimal or high Ca content and high contents of K, S-SO_4 and Zn. For comparison, the plough layer in the control combination, in which spread fertilization was applied in combination with drip irrigation, had low contents of N-NH_4+N-NO_3 and Mn, optimal contents of P, K, Mg, Na, Cl, Fe, Zn, Cu and B, as well as high contents of K, Ca and S-SO_4. Presented data indicate that on the plantation of highbush blueberry established on light soil, which plough layer comprised light loamy sands and the subplough layer consisted of slightly loamy sands, it is difficult to obtain optimal contents of $N\text{-}NH_4$+$N\text{-}NO_3$, while it is easy to cause a high accumulation of K, Ca or $S\text{-}SO_4$.

CONCLUSIONS

1. Application of drip fertigation with the nutrient solutions F-2 and F-3 (pH 5.50) on the plantation of highbush blueberry lowered pH of the plough layer (0–20 cm) in comparison to drip irrigation (water with pH 7.37). No effect of fertigation was found on pH of the subplough layer (20–40 cm). As a result of a reduced pH the content of aluminium in the plough layer increased.

2. Drip fertigation with nutrient solutions F-1 to F-3, in relation to drip irrigation F-0, resulted in increased contents of K, Mg, Fe, Mn, Zn and Cu in the plough layer (0–20 cm), while the application of nutrient solutions F-2 and F-3 increased contents of P, $S\text{-}SO_4$ and B. The effect of fertigation on an increase of nutrient contents in the subplough layer (20–40 cm) was indicated mainly for K and Mg.

3. As a result of fertigation with the use of the nutrient solution with the highest nutrient contents (F-3) the contents of $N\text{-}NO_3$ increased in the subplough layer. In both layers a tendency to increase the contents of $N\text{-}NO_3$ and ($N\text{-}NH_4$+$N\text{-}NO_3$) was shown in comparison to drip irrigation.

4. Fertigation with nutrient solution F-3 reduced the content of chlorides in the plough layer, while the application of nutrient solutions F-2 and F-3 lowered the sodium content.

5. Fertigation with nutrient solutions F-1 to F-3, in relation to drip irrigation F-0, resulted in an increased the EC value of the plough layer. This effect was partly indicated also in the subplough layer.

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

Streszczenie. Stosowanie pożywek do fertygacji może zmieniać chemiczne właściwości gleby. Pożywki dla borówki wysokiej są specyficzne, ze względu na charakterystyczne proporcje między składnikami pokarmowymi oraz kwaśny odczyn. Badania przeprowadzono w latach 2002–2004 na 10-letniej plantacji borówki wysokiej odmiany 'Bluecrop'. Badano wpływ fertygacji 3 pożywkami (F-1, F-2, F-3) w porównaniu z nawadnianiem kroplowym (F-0) na zawartość makro- i mikroelementów oraz sodu i glinu w glebie. Fertygacja kroplowa pożywkami F-1 do F-3, w stosunku do nawadniania kroplowego F-0, zwiększała w warstwie ornej (0–20 cm) gleby zawartość K, Mg, Fe, Mn, Zn i Cu, natomiast pożywkami F-2 i F-3 zawartość P, $S\text{-}SO_4$ i B. Wpływ fertygacji na wzrost zawartości składników w warstwie podornej (20–40 cm) zaznaczył się głównie dla K i Mg. W wyniku stosowania fertygacji pożywką o najwyższej zawartości składników (F-3) nastąpił wzrost zawartości $N\text{-}NO_3$ w warstwie podornej. W obu natomiast warstwach zaznaczyła się tendencja do wzrostu zawartości $N\text{-}NO_3$ w wyniku stosowania fertygacji kroplowej w stosunku do nawadniana kroplowego. Fertygacja pożywką F-3 obniżała zawartość chlorków w warstwie ornej gleby a pożywkami F-2 i F-3 zawartość sodu. W wyniku stosowania fertygacji pożywkami F-2 i F-3 (pH 5.50) następowało obniżanie wartości pH (w H_2O) gleby w warstwie ornej (0–20 cm) w stosunku do nawadniania kroplowego (woda o pH 7,37). Nie stwierdzono natomiast wpływu fertygacji na wartość pH (w H_2O) gleby w warstwie podornej (20–40 cm). W wyniku obniżania wartości pH (w H_2O) zwiększała się zawartość glinu w warstwie ornej gleby. Fertygacja pożywkami F-1 do F-3, w stosunku do nawadniania kroplowego F-0, zwiększała wartość EC warstwy ornej gleby. Efekt ten zaznaczył się częściowo również w warstwie podornej.

Słowa kluczowe: pożywki, makroelementy, mikroelementy, pH gleby, glin

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