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CONTENTS OF MACRO- AND MICROELEMENTS IN ROOT ENVIRONMENT OF GREENHOUSE TOMATO GROWN IN ROCKWOOL AND WOOD FIBER DEPENDING ON NITROGEN LEVELS IN NUTRIENT SOLUTIONS

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Abstract. The aim of investigations conducted in the years 2005–2007 was to determine the chemical composition of nutrient solutions in the root environment of tomato grown in wood fiber and rockwool, under the influence of diverse levels of nitrate nitrogen in the nutrient solution amounting 200, 220 and 240 mg $N\text{-}NO_3 \cdot dm^{-3}$. With an increase in nitrate nitrogen content in nutrient solutions used in plant fertigation a significant increase was observed in the contents of $N\text{-}NO_3$ in nutrient solutions of the root environment, collected from wood fiber and rockwool. No such effect was found for contents of $N\text{-}NH_4$, P, K, Ca, Mg, Fe, Mn, Zn, Cu, B, Na, Cl or pH and EC. In case of wood fiber the following nutrient concentration series was found in nutrient solutions of the root environment in relation to the nutrient solution flowing from the drippers: Na > Cu > Ca > Zn > K > Cl > B > $N\text{-}NO_3$; the following were reduced Fe > Mg > $P\text{-}PO_4$ > $N\text{-}NH_4$ > Mn. Nutrients being concentrated in root environment solutions during tomato growing in rockwool were: Na > Ca > Cu > Fe > Cl > K > Zn > B > $S\text{-}SO_4$ > $N\text{-}NO_3$, while contents of Mg > $P\text{-}PO_4$ > $N\text{-}NH_4$ > Mn decreased. Despite of a wide range of carbon to nitrogen ratio (C:N) in wood fiber (123–127), no significant reduction of nitrates was shown in the root environment. It was a result of adequate application frequency of nutrient solutions during a day.

Key words: substrates, fertilization, $N\text{-}NO_3$ content, pH, EC, C:N ratio

INTRODUCTION

Rockwool, belonging to the group of inert substrates, is the most popular substrate used in intensive tomato growing under covers. However, due to the problems with its

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management and disposal after the completion of the growing cycle, it is attempted to search for organic substrates with advantageous air and water properties, applicable in such growing systems. Organic substrates, in contrast to inert ones, are fully biodegradable, thus their waste management is simple. Examples of organic substrates, the application of which has been investigated in the course of intensive research, include e.g. coconut fiber [Breś and Ruprik 2006a, Hallman and Kobryń 2003, Kobryń et al. 2007], straw [Babik 2006, Nurzyński 2006] or wood fiber [Gajc-Wolska et al. 2008, Komosa 2008, Komosa et al. 2009, Piróg 2008, Piróg and Komosa 2006, Piróg et al. 2009]. Application of organic substrates in intensive growing systems under cover may be connected with biological sorption of nutrients, particularly nitrates [Gruda 2008, Gruda and Schnitzler 1997, Gruda et al. 2000, Hardgrave and Harriman 1995]. In extreme cases microorganisms may contribute to considerable innutrition of plants and deterioration of their growth and yield. It is advisable to conduct studies on the optimization of nitrogen concentration in nutrient solutions used in fertigation with wood fiber as a substrate due to biological sorption of this nutrient. The ratio of carbon to nitrogen (C:N) in the wood fiber is very high and amounted up 123–127.

The objective of this study, was to determine changes of the chemical composition of nutrient solutions in the root environment of tomato grown in wood fiber in relation to rockwool, under the influence of diverse levels of nitrate nitrogen in the nutrient solution amounting from 200 to 240 mg $N\text{-}NO_3\cdot dm^{-3}$.

MATERIALS AND METHODS

Experiments were conducted in the years 2005–2007 in a greenhouse of the Department of Horticultural Plants Nutrition, the Poznań University of Life Sciences. The effect of varied nitrate levels in the nutrient solution applied in fertigation was analyzed in terms of changes in the chemical composition of the rhizosphere of tomato cv. 'Emotion F_1', grown in Agroban rockwool (60 $kg\cdot m^{-3}$, control combination, slabs of 100 × 15 × 7.5 cm) and wood fiber (60 $kg\cdot m^{-3}$, slabes of 100 × 15 × 7.5 cm).

The experiments were established using the randomized complete block design in 4 replications. One replication (plot) consisted of 6 plants growing in 3 slabes (2 plants in 1 slab), at a density of 2.5 $plants\cdot m^{-2}$. Analyses were conducted on 144 plants (3 nitrogen levels × 2 substrates × 4 replications × 6 plants per replication).

Plants were grown using fertigation in the closed system without recirculation of the nutrient solution. Water, on the basis of which the nutrient solution was prepared, contained ($mg\cdot dm^{-3}$): $N\text{-}NH_4$ – tr. (traces), $N\text{-}NO_3$ – 3.7, $P\text{-}PO_4$ – 0.3, K – 1.8, Ca – 57.3, Mg – 13.4, $S\text{-}SO_4$ – 58.3, Fe – 0.080, Mn – 0.080, Zn – 1.648, B – 0.011, Cu – tr., Mo – tr., HCO_3 – 277.5, Na – 22.7, Cl – 42.2, pH – 7.05, EC – 0.74 $mS\cdot cm^{-1}$. A standard nutrient solution was applied for plants, containing the following nutrient contents ($mg\cdot dm^{-3}$): $P\text{-}PO_4$ – 66, K – 380, Ca – 160, Mg – 80, $S\text{-}SO_4$ – 145, Fe – 1.00, Mn – 0.80, Zn – 1.648, B – 0.40, Cu – 0.08, Mo – 0.08, HCO_3 – 42, Na – 30, Cl – 60, pH – 5.50, EC – 3.30 $mS\cdot cm^{-1}$. The levels of nitrogen in the nutrient solutions were: 200, 220 and 240 mg $N\text{-}NO_3\cdot dm^{-3}$. To prepare nutrient solutions there were used following fertilizers: potassium nitrate (13% $N\text{-}NO_3$, 38.2% K), calcium nitrate (14.7% $N\text{-}NO_3$, 18.5% Ca), magnesium nitrate (11% N-NO_3, 9.5% Mg), monopotassium phosphate (22.3% P, 28.2% K), potassium sulphure (44.8% K, 17% S), magnesium sulphure (9.9% Mg, 13% S), Librel FeDP7 (7% Fe), manganese sulphate (32.3% Mn), copper sulphate (25.6% Cu), borax (11.3% B) and sodium molibdate (39.6% Mo). To regulated pH values there were used nitric acid (38%).

The fertilizer rate in the nutrient solution depended on the development phase of plants and climatic conditions in the greenhouse. In the period of intensive yielding of plants and high temperatures (June – July) daily 3.0–3.5 dm^3 nutrient solution per plant were used in 15–20 single doses, with 20–30% effusion of drain water from the slabs.

Samples of nutrient solutions from the drippers, rockwool and wood fiber slabs representing the root zone of plants were collected at the same time of the day, using a syringe in the middle of the distance between plants, in the median axis of the slab, inserting the needle to half slab thickness, at the following dates: 15.05, 15.06, 15.07, 16.08 and 15.09 of each year of the study. The average sample was collected from 10 slabs. Chemical analyses of nutrient solutions were conducted directly in the tested solutions (without their stabilization) using the following methods: N-NH_4 and N-NO_3 – by distillation according to Bremner modified by Starck, P – colorimetrically with ammonium vanadium molybdate, K, Ca, Na – by flame photometry, Cl – nephelometrically with $AgNO_3$, S-SO_4 – nephelometrically with $BaCl_2$, B – colorimetrically with curcumin; Mg, Fe, Mn, Zn, Cu – by atomic absorption spectrometry (AAS, Carl Zeiss Jena); EC – conductometrically and pH – potentiometrically. Results of chemical analyses of nutrient solutions were subjected to statistical analysis using the Duncan test ($\alpha = 0.05$). In case of pH – the values were change into numerical values and then there were done the statistical analysis using the Duncan test ($\alpha = 0.05$). Finally the values was change into logarithmic values (pH).

RESULTS

Macroelements. No significant effect of the level of nitrates in the nutrient solution applied to plants was found for ammonium nitrogen in root environment (tab. 1). In case of rockwool they were within the range 1.47 mg N-$NH_4 \cdot dm^{-3}$ (N-220) to 1.73 mg N-$NH_4 \cdot dm^{-3}$ (N-200), while for wood fiber 1.47 mg N-$NH_4 \cdot dm^{-3}$ (N-240) to 2.03 mg N-$NH_4 \cdot dm^{-3}$ (N-200). The mean content of this nutrient ranged from 1.64 mg N-$NH_4 \cdot dm^{-3}$ (N-220) to 2.02 mg N-$NH_4 \cdot dm^{-3}$ (N-200). Substrates did not differ significantly contents of ammonium.

With an increase in the content of nitrate nitrogen in the nutrient solution applied in fertigation a significant increase was recorded in their concentrations in the root environment (tab. 1). Contents of nitrates for rockwool ranged from 225.9 mg N-$NO_3 \cdot dm^{-3}$ to 255.6 mg N-$NO_3 \cdot dm^{-3}$, while in case of wood fiber these values were slightly lower, ranging from 210.1 mg N-$NO_3 \cdot dm^{-3}$ to 240.6 mg N-$NO_3 \cdot dm^{-3}$ (for 200 and N-240, respectively). Within the analyzed combinations nitrate contents in the nutrient solutions differed significantly and ranged from 209.9 mg N-$NO_3 \cdot dm^{-3}$ to 247.5 mg N-$NO_3 \cdot dm^{-3}$ (for N-200 and N-240, respectively). A marked trend was observed for nitrate contents to decrease in the nutrient solutions collected from wood fiber slabs in relation to rock-

Table 1. The effect of nitrogen levels in nutrient solutions on content of macroelements, EC and pH in nutrient solutions collected from rockwool and wood fiber slabs in growing of tomato (means from 2005–2007)

Tabela 1. Wpływ poziomu azotu w pożywce w uprawie pomidora na zawartość makroskładników, EC i pH w próbkach pobieranych z wełny mineralnej i włókna drzewnego (średnio z 2005–2007)

Sampling place Miejsce pobrania próby	N-level N-200	N-level N-220	N-level N-240	Mean Średnio	N-level N-200	N-level N-220	N-level N-240	Mean Średnio
	mg $N\text{-}NH_4 \cdot dm^{-3}$				mg $Mg \cdot dm^{-3}$			
Dripper	2.30 a	1.97 a	2.06 a	2.11 a	66.2 a	74.6 a	73.8 a	65.5 a
Rockwool	1.73 a	1.47 a	1.57 a	1.59 a	65.5 a	74.8 a	73.9 a	74.3 b
Wood fiber	2.03 a	1.50 a	1.47 a	1.67 a	64.9 a	73.6 a	69.8 a	72.5 b
Mean Średnio	2.02 a	1.64 a	1.70 a		71.5 a	71.4 a	69.4 a	
	mg $N\text{-}NO_3 \cdot dm^{-3}$				mg $S\text{-}SO_4 \cdot dm^{-3}$			
Dripper	193.8 a	221.7 abc	246.2 bc	220.6 a	105.9 a	106.9 a	106.7 a	106.5 a
Rockwool	225.9 abc	239.4 bc	255.6 c	240.3 b	115.4 a	117.4 a	119.2 a	117.3 a
Wood fiber	210.1 a	225.9 abc	240.6 bc	225.5 ab	114.1 a	120.8 a	106.6 a	113.8 a
Mean Średnio	209.9 a	229.0 b	247.5 b		111.8 a	115.0 a	110.8 a	
	mg $P \cdot dm^{-3}$				EC ($mS \cdot cm^{-1}$)			
Dripper	59.3 a	59.7 a	58.7 a	59.2 a	2.91 a	3.00 ab	3.13 abc	3.01 a
Rockwool	51.2 a	52.9 a	49.2 a	51.1 a	3.77 cd	4.02 d	3.86 d	3.88 b
Wood fiber	46.1 a	48.3 a	45.9 a	46.7 a	3.71 cd	3.77 cd	3.65 bcd	3.71 b
Mean Średnio	52.2 a	53.6 a	51.3 a		3.46 a	3.60 a	3.55 a	
	mg $K \cdot dm^{-3}$				pH			
Dripper	367.1 a	366.7 a	376.1 a	369.9 a	5.83 a	6.02 abc	5.89 ab	5.89 a
Rockwool	475.2 a	474.4 a	494.4 a	481.3 b	6.33 bcd	6.38 cd	6.34 bcd	6.34 b
Wood fiber	504.5 a	501.8 a	504.0 a	503.4 b	6.54 d	6.69 d	6.61 d	6.61 c
Mean Średnio	448.9 a	447.6 a	458.2 a		6.13 a	6.30 a	6.21 a	
	mg $Ca \cdot dm^{-3}$							
Dripper	101.4 a	100.0 a	107.4 a	102.9 a				
Rockwool	157.0 c	168.8 c	174.3 c	166.7 c				
Wood fiber	142.1 abc	141.8 abc	146.6 abc	143.5 b				
Mean Średnio	133.5 a	136.9 a	142.8 a					

wool (average 240.3 mg $N\text{-}NO_3 \cdot dm^{-3}$ to 225.5 mg $N\text{-}NO_3 \cdot dm^{-3}$). The above mentioned reduction was probably connected with biological sorption of this nutrient by microorganisms colonizing wood fiber.

No significant changes were found in the contents of phosphorus in the nutrient solutions collected from the root environment with an increase in the level of nitrates in the nutrient solution. Mean phosphorus content ranged from 51.3 mg $P \cdot dm^{-3}$ (N-240) to 53.6 mg $P \cdot dm^{-3}$ (N-220). A trend was observed for the content of this nutrient to decrease in wood fiber in relation to rockwool, average from 51.1 to 46.7 mg $P \cdot dm^{-3}$.

A different tendency than in case of nitrate nitrogen was found for potassium. Mean contents of this nutrient within the investigated combinations were similar and ranged from 447.6 mg $K \cdot dm^{-3}$ (for N-220) to 458.2 mg $K \cdot dm^{-3}$ (for N-240). In nutrient solutions of the root environment a higher concentration of potassium was observed in relation to the nutrient solution applied to plants. A higher potassium content was found for wood fiber (503.4 mg K·dm^{-3}) in comparison to rockwool (481.3 mg K·dm^{-3}).

A diverse content of nitrates in the nutrient solution applied to plants did not have a significant effect on mean contents of calcium, ranging from 133.5 mg Ca·dm^{-3} for N-200 to 142.8 mg Ca·dm^{-3} for N-240. In contrast to wood fiber, there was a tendency to increase of calcium content in the root environment of rockwool with an increase of the level of nitrogen in the nutrient solution emitted from the drippers. For both substrates an increasing concentration of this nutrient was found in the nutrient solutions collected from slabs in relation to the drippers. A significantly lower calcium content was recorded in case of wood fiber (143.5 mg Ca·dm^{-3}) in comparison to rockwool (166.7 mg Ca·dm^{-3}).

Similarly as in case of phosphorus, potassium and calcium, nitrogen level in the nutrient solution did not have a significant effect on contents of magnesium, which ranged from 69.4 mg Mg·dm^{-3} (N-240) to 71.5 mg Mg·dm^{-3} (N-200). For both substrates there was a trend to increase of magnesium in the root environment with an increase of nitrate contents in the nutrient solutions. It was found the concentration effect of magnesium in nutrient solutions collected from rockwool and wood fiber slabs in relation to the drippers.

No significant effect was found for the level of nitrates in the nutrient solution applied to plants on mean content of sulfates, which for the analyzed combinations ranged from 110.8 mg S-SO$_4$·dm^{-3} (N-240) to 115.0 mg S-SO$_4$·dm^{-3} (N-220).

Microelements. No significant effect of nitrates level in the nutrient solutions on mean contents of iron was observed (tab. 2). Concentration of iron was increasing in rockwool (1.74 mg Fe·dm^{-3}) in relation to wood fiber (1.26 mg Fe·dm^{-3}). Iron content was similar in nutrient solutions applied to plants and in nutrient solutions sampled from wood fiber slabs.

Similarly as in case of iron, no modifying effect of nitrates level on contents of manganese was found in tested nutrient solutions. They ranged from 0.46 mg Mn·dm^{-3} (N-240) to 0.50 mg Mn·dm^{-3} (N-200). Manganese in both tested substrate was passing into insoluble forms as the effect of fixation process.

Contents of zinc, similarly as for iron and manganese, were not significantly modified with an increase level of nitrates in the nutrient solution. It was ranging from 0.62 mg Zn·dm^{-3} (for N-240) to 0.67 mg Zn·dm^{-3} (for N-220).

The level of nitrogen in the nutrient solution did not diversify the content of copper in the root environment. Copper, in contrast to manganese, was significantly concentrated in nutrient solutions collected from slabs in relation to the nutrient solution applied to plants.

Increasing levels of nitrates in the nutrient solution used in fertigation did not have a modifying effect on boron contents. Mean content of this nutrient for each nitrogen levels in the nutrient solutions was 0.42 mg B·dm^{-3}. It was found a significant increase of boron concentration both in rockwool and wood fiber slabs.

Similarly as for the previously analyzed microelements, no differentiating effect on chloride content was observed in the root environment depending on nitrogen levels in the nutrient solution. They covered the range from 40.3 mg Cl·dm^{-3} (N-240) to 42.6 mg Cl·dm^{-3} (N-220). Chlorides, similarly as copper and boron, were significantly concentrated both in wood fiber and rockwool in relation to nutrient solution applied to plants.

Table 2. The effect of nitrogen levels in nutrient solutions on content of microelements and sodium collected from rockwool and wood fiber slabs in growing of tomato (means from 2005–2007)

Tabela 2. Wpływ poziomu azotu w pożywce w uprawie pomidora na zawartość mikroskładników i sodu w próbkach pobieranych z wełny mineralnej i włókna drzewnego (średnio z 2005-2007)

Sampling place Miejsce pobrania próby	N-level – poziom N			Mean Średnio	N-level – Poziom N			Mean Średnio
	N-200	N-220	N-240		N-200	N-220	N-240	
	mg Fe·dm^{-3}				mg B·dm^{-3}			
Dripper	1.28 a	1.24 a	1.29 a	1.27 a	0.39 a	0.39 a	0.39 a	0.39 a
Rockwool	1.74 b	1.80 b	1.68 b	1.74 b	0.44 a	0.43 a	0.44 a	0.44 b
Wood fiber	1.28 a	1.22 a	1.27 a	1.26 a	0.43 a	0.43 a	0.44 a	0.43 b
Mean Średnio	1.43 a	1.42 a	1.42 a		0.42 a	0.42 a	0.42 a	
	mg Mn·dm^{-3}				mg Na·dm^{-3}			
Dripper	0.75 b	0.73 b	0.72 b	0.74 b	35.8 a	34.8 a	35.9 a	35.4 a
Rockwool	0.36 a	0.28 a	0.28 a	0.31 a	68.9 b	73.1 b	69.6 b	70.5 b
Wood fiber	0.39 a	0.40 a	0.36 a	0.39 a	70.1 b	69.0 b	67.9 b	69.0 b
Mean Średno	0.50 a	0.47 a	0.46 a		58.3 a	59.0 a	57.8 a	
	mg Zn·dm^{-3}				mg Cl·dm^{-3}			
Dripper	0.55 a	0.58 a	0.49 a	0.54 a	34.2 a	33.3 a	33.7 a	33.7 a
Rockwool	0.67 a	0.73 a	0.67 a	0.69 a	44.7 b	48.4 b	43.8 b	45.6 b
Wood fiber	0.70 a	0.71 a	0.70 a	0.70 a	45.0 b	46.2 b	43.4 b	44.9 b
Mean Średnio	0.64 a	0.67 a	0.62 a		41.3 a	42.6 a	40.3 a	
	mg Cu·dm^{-3}							
Dripper	0.072 a	0.078 a	0.075 a	0.075 a				
Rockwool	0.099 a	0.112 a	0.099 a	0.103 ab				
Wood fiber	0.131 a	0.110 a	0.117 a	0.119 b				
Mean Średnio	0.101 a	0.100 a	0.097 a					

The level of nitrogen in nutrient solution did not have a significant effect on sodium contents which was within the range 57.8 mg Na·dm^{-3} (N-240) to 59.0 mg Na·dm^{-3} (N-220). Contents of sodium, similarly as chlorides, were significantly concentrated in nutrient solutions sampled from rockwool and wood fiber slabs.

There was appeared a significant increase of EC as the effect of increasing concentrations of nitrates, potassium, calcium, magnesium, sodium and chlorides in nutrient solutions collected from the root environment (tab. 1). The highest EC was recorded in the nutrient solution sampled from rockwool and wood fiber slabs at the level of 220 mg N-NO_3·dm^{-3} (4.02 and 3.77 mS·cm^{-1}, respectively), while in combination N-200 was markedly lower – 3.77 and 3.71 mS·cm^{-1}, respectively.

No significant effect of nitrogen levels on pH of nutrient solutions was recorded (tab. 1). Mean pH ranged from 6.13 to 6.30 (for N-200 and N-220, respectively). As a consequence of potassium, calcium, magnesium and sodium accumulation in both tested substrates a significant alkalization was noticed in the root environment.

DISCUSSION

Rank of nutrient concentrations effect in root environment. The concentrations effect of nutrients in the root environment of tomato grown in rockwool and wood fiber was shown (tab. 3). Nutrients were concentrated (the mean of the tested combinations) in nutrient solutions collected from the root environment of tomato grown in rockwool in the following series: Na > Ca > Cu > Fe > Cl > K > Zn > B > S-SO_4 > N-NO_3, while decreasing concentrations were found for Mg > P-PO_4 > N-NH_4 > Mn. Similar results of studies were reported by Komosa et al. [2009], where this series was: Na > Fe > Ca > N-NH_4 > Cu > K > Cl > N-NO_3 > Mg > S-SO_4 >B. This data were confirmed also in study of Pawlińska [2003].

Table 3. An increase or decrease (%) of nutrient contents in nutrient solutions collected from rockwool and wood fiber in relation to nutrient solution applied to tomato grown in that substrates (means from 2005–2007)

Tabela 3. Wzrost lub spadek (%) zawartości składników odżywczych w pożywkach pobieranych z wełny mineralnej i włókna drzewnego w porównaniu z roztworem odżywczym stosownym w uprawie pomidora w tych podłożach (średnio z 2005-2007)

Nutrient Składnik	N-level							
	N-200		N-220		N-240		Mean – Średnio	
	Rockwool	Wood fiber	Rockwool	Wood fiber	Rockwool	Wood fiber	Rockwool	Wood fiber
N-NH_4	-24.8	-11.7	-25.4	-28.6	-23.8	-28.6	-24.7	-23.0
N-NO_3	+16.6	+8.4	+8.0	+2.3	+3.8	-2.3	+9.5	+1.3
P-PO_4	-13.7	-22.3	-11.4	-21.8	-16.2	-21.8	-13.8	-22.0
K	+29.4	+37.4	+29.4	+34.0	+31.5	+34.0	+30.1	+35.1
Ca	+54.8	+40.1	+68.8	+41.8	+62.3	+36.5	+60.2	+39.5
Mg	-1.1	-2.0	+0.3	-5.4	+0.1	-5.4	-0.2	-4.3
S-SO_4	+9.0	+7.7	+9.8	-0.1	+11.7	-0.1	+10.2	+2.5
Fe	+35.9	0.0	+45.2	-1.6	+30.2	-1.6	+37.1	-1.1
Mn	-52.0	-48.0	-61.6	-50.0	-61.1	-50.0	-58.2	-49.3
Zn	+21.8	+27.3	+25.9	+42.9	+36.7	+42.9	+28.1	+37.7
Cu	+37.5	+81.9	+43.6	+56.0	+32.0	+56.0	+37.7	+64.6
B	+12.8	+10.3	+10.3	+12.8	+12.8	+12.8	+12.0	+12.0
Cl	+30.7	+31.6	+45.3	+28.8	+30.0	+28.8	+35.3	+29.7
Na	+92.5	+95.8	+110.1	+89.1	+93.9	+89.1	+98.8	+91.3
EC	+29.6	+27.5	+34.0	+16.6	+23.3	+16.6	+29.0	+20.2

In wood fiber the series of increasing concentrations was following: Na > Cu > Ca > Zn > K > Cl > B > N-NO_3, there were reduction for Fe > Mg > P-PO_4 > N-NH_4 >Mn. In earlier study Komosa et al. [2009] reported the following rank: Na > Zn > Ca > N-NO_3 > K > Mg > Cl > S-SO_4 > B. The above mentioned authors, similarly as in this study, indicated a reduction of contents for: N-NH_4, P-PO_4, Fe and Mn. Similar changes for tomato growing in coconut fiber were determined by Breś and Ruprik [2006b].

Both in rockwool and wood fiber, a significant alkalization of nutrient solutions was recorded in the root zone of plants in relation to nutrient solutions applied to plants. Similarly as in a study by Komosa et al. [2009], a statistically significant trend for higher alkalization of nutrient solutions was observed for wood fiber (pH 6.61) in relation to rockwool (pH 6.35). These results are in coincident with the earlier studies by

Breś and Ruprik [2006b] conducted on coconut fiber, as well as by Pawlińska [2003] and Komosa and Olech [1996b] for tomato grown in rockwool.

There is a limited data in literature concerning changes in the chemical composition of nutrient solutions in the root environment of tomato grown in organic substrates. As a result of transpiration predominating over nutrient uptake the concentrations of nutrients and EC in these substrates increased. Similar effects were found by Bőhme [1995], Bloemhard and van Moolenbroek [1995], Nurzyński [2004], Dyśko and Kowalczyk [2005], Breś and Ruprik [2006b]. Results of this study were within the optimal range of EC for nutrient solutions in the root environment, amounting to 2.8–4.2 $mS \cdot cm^{-1}$, as was reported by Wysocka-Owczarek [1998]. Komosa and Olech [1996a] stated that an increase of nutrient solution EC in root environment is a consequence of water transpiration predominating over nutrient uptake by aboveground parts of plants and selective ion uptake. Concentration of nutrients in the root environment of tomato grown in wood fiber was confirmed by studies of Breś and Ruprik [2006b], Komosa et al. [2009] for coconut fiber, Pawlińska [2003], Nurzyński [2004], Dyśko and Kowalczyk [2005] for rockwool, and Piróg et al. [2009] for growing of cucumber in wood fiber.

Chohura [2000] reported that for tomato in grown in rockwool the concentration of copper was strongly increased, while Pawlińska [2003] reported that strongest concentration was for iron, boron and sodium. Komosa et al. [2009] stated that concentration of sodium increased the most in wood fiber. A significant concentration effect of this nutrient in tomato growing in coconut fiber was also recorded by Breś and Ruprik [2006b].

It may be stated that in despite of a very wide C:N ratio in wood fiber, amounting to 123–127, and possibility of nitrogen biological sorption occurrence, no significant reduction in the contents of nitrates was observed in the nutrient solutions collected from root environment.

CONCLUSIONS

Based on the conducted investigations concerning changes of nutrient contents in the root environment of tomato grown in rockwool and wood fiber, under the influence of increasing nitrogen levels in nutrient solutions it was found:

1. With an increase in the content of nitrates in nutrient solutions applied in plant fertigation, a significant increase of $N\text{-}NO_3$ contents was recorded in nutrient solutions in the root environment, sampled from wood fiber and rockwool. Such an effect was not shown for contents of $N\text{-}NH_4$, P, K, Ca, Mg, Fe, Mn, Zn, Cu, B, Na, Cl, as well as pH and EC.

2. In tomato growing in both substrates the contents of Na, Cu and Ca increased, whereas the contents of Mg, $P\text{-}PO_4$, $N\text{-}NH_4$ and Mn in the root environment did not change. The series of increasing concentrations for wood fiber was as follows: Na > Cu > Ca > Zn > K > Cl > B > $S\text{-}SO_4$ > $N\text{-}NO_3$; while the concentrations did not increase for Fe > Mg > $P\text{-}PO_4$ > $N\text{-}NH_4$ > Mn. For growing in rockwool this series was: Na > Ca > Cu > Fe > Cl > K > Zn > B > $S\text{-}SO_4$ > $N\text{-}NO_3$, with decreasing concentrations for Mg > $P\text{-}PO_4$ > $N\text{-}NH_4$ > Mn.

3. To disadvantageous of nutrient contents in the root environment should be included accumulation of sodium and chlorides in both substrates and lowering contents

of magnesium, phosphorus, ammonium and manganese. An increase in the contents of copper, calcium, zinc, potassium, boron, sulfates and nitrates in the root environment in both substrates is not a negative phenomenon, however this effect should be included for estimating optimal nutrient solutions for growing tomato in rockwool and wood fiber.

REFERENCES

Babik J., 2006. Podłoża organiczne do uprawy ogórka szklarniowego, alternatywne dla wełny mineralnej, Acta Agrophysica, 2006, 7(4), 809–820.

Bloemhard C.M.J., van Moolenbroek J., 1995. Management of mineral elements of roses grown in closed rockwool systems. Acta Hort. 401, 481–489.

Bőhme M., 1995. Evaluation of organic, synthetic and mineral substrates for hydroponically grown cucumber. Acta Hort. 401, 209–217.

Breś W., Ruprik B., 2006a. Uprawa drobnoowocowych odmian pomidora szklarniowego we włóknie kokosowym przy zróżnicowanym nawożeniu azotem i potasem. Cz. I. Plonowanie. Acta Agrophysica 7(3), 527–537.

Breś W., Ruprik B., 2006b. Uprawa drobnoowocowych odmian pomidora szklarniowego we włóknie kokosowym przy zróżnicowanym nawożeniu azotem i potasem. Cz. II. Zmiany składu chemicznego pożywek zachodzące w środowisku korzeniowym. Acta Agrophysica 7(3), 539–548.

Chohura P., 2000. Zawartość składników pokarmowych w strefie korzeniowej, stan odżywienia i plonowanie pomidora szklarniowego w podłożach inertnych. Praca doktorska. AR Wrocław, 35–83.

Dyśko J., Kowalczyk W., 2005. Changes of macro and micronutrients concentrations in root medium and drainage water during tomato cultivation in rockwool. Veget. Crops Res. Bull. 62, 96–111.

Gajc-Wolska J., Bujalski D., Chrzanowka A., 2008. Effect of a substrate on yielding and quality of greenhouse cucumber fruits. J. Elementology 13(2), 205–210.

Gruda N., 2008. The effect of wood fiber mulch on water retention, soil temperature and growth of vegetable plants. J. Sustainable Agric., 32 (4), 629–643.

Gruda N., Schnitzler W.H., 1997. The influence of organic substrates on growth and physiological parameters of vegetable seedlings. Acta Hort. 450, 487–494.

Gruda N., Tucher S., Schnitzler W.H., 2000. N-immobilization of wood fiber substrates in the production of tomato transplants (*Lycopersicon esculentum* Mill.(L.) Karst. Ex. Farw.). J. Appl. Bot., 74, 32–37.

Hallman E., Kobryń J., 2003. Yield and quality of cherry tomato (*Lycopersicon esculentum* var. *cerasiforme*) cultivated on rockwool and cocofiber. Acta Hort. 614, 693–697.

Hardgrave M., Harriman M., 1995. Development of organic substrates for hydroponic cucumber production. Acta Hort. 401, 219–224.

Kobryń J. Abukhovich A., Kowalczyk K., 2007. Wysokość i jakość plonu owoców pomidora drobnoowocowego w uprawie na włóknie kokosowym i wełnie mineralnej. Rocz. AR Pozn. 383, Ogrodnictwo 41, 523–528

Komosa A., 2008. Czy stosunek C:N we włóknie drzewnym ogranicza plonowanie pomidora szklarniowego? Mat. konf. „Nowe podłoża organiczne w uprawie roślin pod osłonami". 30 stycznia 2008. Warszawa, 10.

Komosa A., Olech R., 1996a. Zróżnicowanie składu pożywki w zamkniętym systemie nawożenia pomidora szklarniowego. Cz. I. Makroelementy. Prace Kom. Nauk Roln. i Kom. Nauk Leśnych. PTPN 81, 253–260.

Komosa A., Olech R., 1996b. Zróżnicowanie składu pożywki w zamkniętym systemie nawożenia pomidora szklarniowego. Cz. II. Mikroelementy. Prace Kom. Nauk Roln. i Kom. Nauk Leśnych. PTPN 81, 261–266.

Komosa A., Piróg J., Kleiber T., 2009. Changes of macro and micronutrients in the root environment of greenhouse tomato grown in fiber wood. Veg. Crps Res. Bull. 70, 71–80,

Nurzyński J., 2004. Wpływ koncentracji składników pokarmowych w podłożach z wełny mineralnej, torfu oraz piasku na plonowanie pomidora szklarniowego. X Symp. Nauk. Efektywność stosowania nawozów w uprawach ogrodniczych. 261–268.

Nurzyński J., 2006. Plonowanie i skład chemiczny pomidora uprawianego w szklarni w podłożach ekologicznych. Acta Agrophysica 7(3), 681–690.

Pawlińska A., 2003. Wpływ podłoży i pożywek na skład chemiczny rizosfery, stan odżywienia roślin i plonowanie pomidora szklarniowego. Praca doktorska. AR Poznań, 44–105.

Piróg J., 2008. Plonowanie ogórka szklarniowego we włóknie drzewnym Agroflex. Mat. Konf. Nowe podłoża organiczne w uprawie roślin ogrodniczych pod osłonami. 30 stycznia 2008. Warszawa, 9.

Piróg J., Komosa A., 2006. Wpływ podłoży i odmiany na wysokość i jakość plonu pomidora szklarniowego. Acta Agrophysica 7(3), 699–707.

Piróg J., Komosa A., Markiewicz B., 2009. The effect of wood fiber density on the content of macro and microelements in the root environment of greenhouse cucumber. Veg. Crps Res. Bull. 70, 81–89.

Wysocka-Owczarek M., 1998. Pomidory pod osłonami. Uprawa tradycyjna i nowoczesna. Hortpress sp. z o.o. Warszawa, 155–187.

ZAWARTOŚĆ MAKRO- I MIKROELEMENTÓW W ŚRODOWISKU KORZENIOWYM POMIDORA SZKLARNIOWEGO UPRAWIANEGO W WEŁNIE MINERALNEJ I WŁÓKNIE DRZEWNYM W ZALEŻNOŚCI OD ZAWARTOŚCI AZOTU W POŻYWKACH

Streszczenie. Celem przeprowadzonych badań (2005–2007) było określenie zmian zawartości makro i mikroelementów oraz sodu w pożywkach pobieranych ze środowiska korzeniowego pomidora, uprawianego we włóknie drzewnym i wełnie mineralnej, pod wpływem zróżnicowanych poziomów azotu azotanowego w pożywkach, wynoszących 200, 220, 240 mg $N\text{-}NO_3 \cdot dm^{-3}$. Ze wzrostem zawartości azotu azotanowego w pożywkach stosowanych do fertygacji roślin stwierdzono istotny wzrost zawartości $N\text{-}NO_3$ w pożywkach pobieranych ze środowiska korzeniowego roślin uprawianych we włóknie drzewnym i wełnie mineralnej. Wpływu takiego nie wykazano dla zawartości $N\text{-}NH_4$, P, K, Ca, Mg, Fe, Mn, Zn, Cu, B, Na, Cl, oraz pH i EC. W przypadku włókna drzewnego stwierdzono następujący szereg zatężania składników w pożywkach pobieranych ze środowiska korzeniowego, w stosunku do pożywki dostarczanej roślinom: Na > Cu > Ca > Zn > K > Cl > B > $N\text{-}NO_3$; obniżeniu ulegały zawartości Fe > Mg > $P\text{-}PO_4$ > $N\text{-}NH_4$ > Mn. Składnikami ulegającymi zatężaniu w pożywkach pobieranych ze strefy korzeniowej w uprawie pomidora w wełnie mineralnej były: Na > Ca > Cu > Fe > Cl > K > Zn > B > $S\text{-}SO_4$ > $N\text{-}NO_3$, natomiast obniżaniu ulegały Mg > $P\text{-}PO_4$ > $N\text{-}NH_4$ > Mn. Mimo szerokiego stosunku węgla do azotu we włóknie drzewnym, wynoszącym C:N = (123–127) i możliwości wystąpienia sorpcji biologicznej, nie wykazano istotnego obniżenia zawartości azotu azotanowego w pożywkach pobieranych ze strefy korzeniowej roślin. Było to wynikiem odpowiedniej częstotliwość dostarczania pożywki roślinom w ciągu doby.

Słowa kluczowe: podłoża, nawożenie, zawartość $N\text{-}NO_3$, pH, EC, stosunek C:N

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