THE INFLUENCE OF pH OF NUTRIENT SOLUTION ON YIELD AND NUTRITIONAL STATUS OF TOMATO PLANTS GROWN IN SOILLESS CULTURE SYSTEM

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Summary
The aim of the studies conducted in the years 2004-2006 was determination the influence of nutrient solution of different pH on the yield and nutritional status of tomato plants grown in soilless culture in organic and inert medium. Tomato plants were grown on slabs made of shredded rye straw and on slabs of peat and rockwool. The plants were fertilized with standard nutrient solution of different pH: 4.5, 5.0, 5.5, 6.0, 6.5. Nutrient solution pH and the kind of applied growing substrates were exerted significantly influence on the height of total and marketable yield of tomato cv. Blitz F1. Early yield was not depended on pH of nutrient solution and the kind of using substrates. The highest total and marketable yield was observed in tomato grown in rockwool slabs. For all the growing media, the highest yield of tomatoes was obtained after feeding the plants with the nutrient solution of pH 5.5. The kind of growing substrates and pH of nutrient solution were significantly differenced the nutritional status of tomato plants. Despite of considerable differentiation of means concentration of mineral nutrient in tomato leaves, the plant growth and development were proper. Concentration of mineral nutrients was comprised at the optimum range of nutritional status of tomato plants. The pH of nutrient solution at the range of 4.5-6.0 was not exerted significantly influence on nutritional status of tomato plants with nitrogen, potassium and magnesium. With the increase of the pH nutrient solution the average phosphorus, iron and manganese content was decreased. The higher concentration of nitrogen, calcium and magnesium was occurred in tomato plants cultivated in organic substrates than in rockwool. The phosphorus and manganese content was higher in the leaves of tomato plants grown in rockwool compared to those in the organic media. Tomato plants grown in the straw substrate contained lower concentrations of potassium and iron and more calcium in comparison to peat.

key words: pH, nutrient solution, rockwool, straw, peat, tomato
INTRODUCTION

The soilless culture system is characterized with ability of precision plant nutrition, growth control and consistently to obtain higher yield in comparison to conventional tillage. In this kind of cultivation method the mineral and organic growing media are used. Rockwool as an inert medium is the most popular mineral substrate (Komosa 2002). It is estimated that about 1200 ha of tomatoes in Poland are cultivated in rockwool. The control of nutritional program is easier and more precisely in inert media indicated the physical stability and treated as a chemical passive. Organic substrates have a high sorption complex which makes difficult precisely maintenance of optimum mineral elements concentration in rhizosphere. The availability of some nutrients directly depends on the pH of the root zone. The influence of pH of nutrient solution on the nutrient uptake degree is greater in inert medium than in organic substrates where the pH of root zone is modified by the organic matter. According to Dyśko et al. (2008) different pH of nutrient solution applied in soilless tomato culture system in organic substrates was lesser extent modified the pH of the root growth zone than in inert medium. pH of nutrient solution was exerted the directly influence on the dissociation degree of dissolved salts, stability of complex compounds, the rate and course of oxidation and reduction reactions and precipitation of soluble sediments (Rijck & Schrevens 1998 a, b). Some of the nutrients like phosphorus, calcium, iron and manganese come into that kind of reactions in the root zone. Misapplication of pH of nutrient solution could exerted negative influence on nutritional status of tomato plants (Adams 1996, Dyśko et al. 2008, Komosa et al. 2004). According to Komosa et al. (2004) different pH of nutrient solution applied in tomato cultivation in rockwool caused significantly changes of nitrogen, phosphorus, potassium and sulphur content. The changes of calcium and magnesium content were observed in some years but it did not change the general assessment of nutritional status of tomato plants.

The aim of this work was to determine the effect of nutrient solution pH on the yield and nutritional status of plants in soilless culture of tomato grown in organic and inert medium.

MATERIALS AND METHODS

The experimental work was conducted in the years 2004-2006 in the greenhouse of Research Institute of Vegetable Crops in Skierniewice. The research was carried out on Blitz F1 greenhouse variety of tomato. The experiment was set up in a two-factorial design in an independent system with four replications. Shredded rye straw was used to make cultivation mats in the shape of 100 cm long, 20 cm wide and 10 cm thick. Slabs of the same dimensions were also made of peat. Each slab of a substrate was used to grow 3 tomato plants. The experimental plot size was 3 m². The check used in the experiments was Grodan-Master rockwool in 100 x 20 x 7.5 cm slabs. The plants were planted in a permanent place of cultivation in early April and grown in an extended cycle
until 15th of October. The require pH of the nutrient solution: 4.5, 5.0, 5.5, 6.0 and 6.5 was obtained by adding to water nitric and hydrochloric acid. The pH of the nutrient solution - 6.5 was achieved by using 65% HNO₃. Lower pH level in combinations of pH: 4.5, 5.0, 5.5 and 6.0 was obtained adding 33% of HCl. The amount of acid needed to bring the nutrient solution to the required pH level was determined on the basis of a water acidification curve. Parameters of the applied nutrient solution were as following: pH 4.5-6.5, depending on the combination, EC – 2.0-3.0 mS·cm⁻¹, nutrients content in mg·dm⁻³: N – 200-260, P – 40, K – 220-380, Mg – 60-80, Ca – 180-200, S-SO₄ – 80-120, Fe – 2.5, Mn – 0.8, B – 0.43, Zn – 0.33, Cu – 0.1, Mo – 0.05. The water of following composition was used to prepare the nutrient solution (in mg·dm⁻³): HCO₃ – 349, N-NO₃ – 0.25, N-NH₄ – 0.05, P – 0.05, K – 2.72, Ca – 101, Mg – 15.00, Na – 10.50, Cl – 12.90, S – SO₄ – 33.50, Fe – 0.04, Mn – 0.02, Cu – 0.02, Zn – 1.68, B – 0.02, EC – 0.56 mS·cm⁻¹, pH – 7.2, total hardness – 17.6 °dH. The nutritional status of tomato plants on the basis of a macroelements (N, P, K, Mg) and microelements (Fe, Mn) content in leaves was analyzed once a month (seven times during vegetation season). Fifth full developed leaf from the plant top was used as indicator. Nitrogen concentration was determined by using Kjeldahl’s method and the other elements were measured with plasma spectrometer (ICP) OPTIMA 2000 D. Contamination of elements in the water was taken into consideration in preparing of nutrient solution. Tomato fruits were gathered twice a week. Experimental observations:
- early yield (1/3 of harvest time, in 35 days of cultivation),
- marketable yield – tomato fruits with diameter >60 mm - extra class, 45-60 mm - I class and 35-45 mm - II class,
- total yield of tomato fruits gathered during the harvest.

The results concerned yielding and nutritional status of tomato were evaluated statistically with an analysis of variance in two-factorial design in an independent system. It was used to estimated the significance of differences. Mean values were compared with Newman-Keul’s test at P=0.05.

**RESULTS**

Results of the conducted experiments proved that pH of applied nutrient solution and the kind of substrates were significantly influenced on the total and marketable yield of tomato but the interaction between pH of nutrient solution and the kind of applied media was not observed (Table 2, 3). Early yield was not depend on pH of nutrient solution and the kind of using substrates (Table 1).

The highest total and marketable yield with the smallest part of unmarketable tomato fruits was obtained from tomato plants cultivated in rockwool. This yield was significantly higher than in the organic media (straw, peat). For all the growing media, the highest total and marketable yield of tomatoes was obtained after feeding the plants with the nutrient solutions of pH 5.5. The marketable yield obtained from plants grown with the nutrient solution of pH 5.5 was significantly higher in relation to the yield obtained at pH 6.5 but it was not sig-
nificantly differ from the yields obtained at pH 4.5, 5.0 and 6.0. The lowest total yield was gathered after using a nutrient solution with a high pH value – 6.5. This yield was not significantly different from the yields obtained at pH 4.5 but it was significantly lower in comparison to the other tested pH nutrient solution.

Table 1. The effect of pH of nutrient solution and type of growing medium on the early yield of greenhouse tomato cv. Blitz F1 (2004-2006)

<table>
<thead>
<tr>
<th>pH</th>
<th>Yield in kg m⁻²</th>
<th>straw</th>
<th>peat</th>
<th>rockwool</th>
<th>mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5</td>
<td>9.84</td>
<td>9.98</td>
<td>12.16</td>
<td>10.66 a</td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td>10.66</td>
<td>10.01</td>
<td>10.86</td>
<td>10.51 a</td>
<td></td>
</tr>
<tr>
<td>5.5</td>
<td>10.18</td>
<td>10.92</td>
<td>11.59</td>
<td>10.90 a</td>
<td></td>
</tr>
<tr>
<td>6.0</td>
<td>10.51</td>
<td>10.72</td>
<td>11.51</td>
<td>10.92 a</td>
<td></td>
</tr>
<tr>
<td>6.5</td>
<td>10.18</td>
<td>10.02</td>
<td>11.60</td>
<td>10.60 a</td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td>10.27 a</td>
<td>10.33 a</td>
<td>11.54 a</td>
<td>10.72 a</td>
<td></td>
</tr>
</tbody>
</table>

Note: Means followed by the same letters are not significantly different according to Newman-Keul’s test at P=0.05

Table 2. The effect of pH of nutrient solution and type of growing medium on the marketable yield of greenhouse tomato cv. Blitz F1 (2004-2006)

<table>
<thead>
<tr>
<th>pH</th>
<th>Yield in kg m⁻²</th>
<th>straw</th>
<th>peat</th>
<th>rockwool</th>
<th>mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5</td>
<td>39.97</td>
<td>38.31</td>
<td>45.63</td>
<td>41.30 ab</td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td>37.14</td>
<td>40.84</td>
<td>46.14</td>
<td>41.38 ab</td>
<td></td>
</tr>
<tr>
<td>5.5</td>
<td>41.58</td>
<td>41.87</td>
<td>47.53</td>
<td>43.66 a</td>
<td></td>
</tr>
<tr>
<td>6.0</td>
<td>39.01</td>
<td>40.87</td>
<td>45.32</td>
<td>41.73 ab</td>
<td></td>
</tr>
<tr>
<td>6.5</td>
<td>36.47</td>
<td>38.25</td>
<td>39.23</td>
<td>37.98 b</td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td>38.83 b</td>
<td>40.03 b</td>
<td>44.77 a</td>
<td>41.21</td>
<td></td>
</tr>
</tbody>
</table>

Note: see Table 1

Table 3. The effect of pH of nutrient solution and type of growing medium on the total yield of greenhouse tomato cv. Blitz F1 (2004-2006)

<table>
<thead>
<tr>
<th>pH</th>
<th>Yield in kg m⁻²</th>
<th>straw</th>
<th>peat</th>
<th>rockwool</th>
<th>mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5</td>
<td>41.34</td>
<td>40.09</td>
<td>44.75</td>
<td>42.06 bc</td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td>38.84</td>
<td>43.21</td>
<td>47.74</td>
<td>43.26 ab</td>
<td></td>
</tr>
<tr>
<td>5.5</td>
<td>43.31</td>
<td>43.76</td>
<td>49.42</td>
<td>45.50 a</td>
<td></td>
</tr>
<tr>
<td>6.0</td>
<td>40.71</td>
<td>42.64</td>
<td>47.70</td>
<td>43.68 ab</td>
<td></td>
</tr>
<tr>
<td>6.5</td>
<td>38.10</td>
<td>39.99</td>
<td>40.41</td>
<td>39.50 c</td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td>40.46 b</td>
<td>41.94 b</td>
<td>46.00 a</td>
<td>42.80</td>
<td></td>
</tr>
</tbody>
</table>

Note: see Table 1

A literature review indicates on a lack of informations concerning the influence of pH of nutrient solution applied in soilless culture system in organic
substrates on the tomato yield. The experimental studies on the effect of pH of nutrient solution have involved mainly inert substrates and there have been no reports concerning organic growing media (Chohura et al. 2004, Kowalczyk 2003). According to authors the pH of nutrient solution was not influenced on early yield but higher than recommended pH - 5.5 was reduced the yield of tomato fruits.

In the experiments of Willumsen (1980) with tomato aquacultures, differ pH levels (4.5-6.5) of the nutrient solutions were not observed to have an effect on marketable yield. However nutrient solution of pH 4.5 was found to reduce fruit size.

The influence of pH of nutrient solution and the kind of substrates on the nutritional status of tomato plants cv. Blitz F₁ was shown on Figures 1-7.

Different pH level of the nutrient solutions was not exerted significantly influence on nitrogen content in tomato leaves but the kind of applied substrates significantly differentiated the nutritional status of plants with this element (Fig. 1). Nitrogen content in plant leaves was high in all the growing media and it was amounted 4.4-5.9% N in d.m. The higher nitrogen content was observed in plants grown in organic substrates. In the experiments of Komosa et al. (2004) an increase of pH of nutrient solution above 5.5 was caused reduction of nitrogen content in tomato plants cultivated in rockwool. The pH of applied nutrient solutions and the kind of substrate significantly differentiated the nutritional status of plants with phosphorus (Fig. 2).

![Fig. 1. The effect of pH of nutrient solution and type of growing medium on the N content in tomato leaves (2004-2006)]](image-url)
Note: see Table 1

Fig. 2. The effect of pH of nutrient solution and type of growing medium on the P content in tomato leaves (2004-2006)

Tomato plants grown in rockwool were contained more phosphorus in comparison to plants cultivated in peat and straw. It was caused by decrease of phosphorus availability in organic media where higher pH of root zone was observed during the whole cultivation period. According to Nurzyński et al. (1995) the high pH of root growing zone was caused worse nutritional status of plants with phosphorus.

With an increase of the pH of nutrient solution, the phosphorus content in tomato plants was decreased without significantly differences at pH of 5.5 and 6.0. It was also proved in the studies of Kowalczyk & Kaniszewski (2005). The influence of pH of nutrient solution on the nutritional status of tomato plants with nitrogen and potassium was not observed (Fig. 3).

The higher potassium content in plants grown in rockwool and peat and significantly lower in straw was noticed. Pawlińska & Komosa (2006) were proved higher potassium content in an indicator parts of tomato plants cultivated in inert medium than in organic substrate. The highest calcium content was observed in tomato leaves fertilized of nutrient solution with pH of 6.0 and significantly lower with pH of 4.5, 5.0 and 6.5 (Fig. 4). The average calcium content in leaves of plants grown in the straw was significantly higher in comparison to plants cultivated in peat and rockwool. Differentiation of pH of nutrient solution was not influenced on magnesium nutritional status of plants (Fig. 5). Plants grown in organic substrates were characterized with significantly higher calcium and magnesium content than plants cultivated in rockwool. Nurzyński (2006) was not obtained a significantly influence of substrate on the calcium and magnesium nutritional status of plants in comparison of tomato
cultivation in the straw to rockwool. The iron and manganese content in leaves was strongly depended on pH of nutrient solution and the kind of applied substrate (Fig. 6, 7). As the pH level of the nutrient solution was decreased the iron and manganese content in tomato leaves was increased. The highest concentration of iron and manganese in an indicator parts of tomato plants was recorded when the pH of the applied nutrient solution was amounted of 4.5, 5.0. Compared to rockwool and peat substrate there was observed significantly lower iron content in leaves of plants grown in the straw. The best manganese nutritional status of tomato plants was proved during cultivation in rockwool. The average manganese content in tomato plants grown in rockwool was higher at about 60% in comparison to plants cultivated in peat substrate and in the straw. Despite of application different pH level of the nutrient solution in root growing zone in organic substrates, the high pH of nutrient solution was stabilized and it was limited manganese availability. The earlier of authors works proved that organic substrates characterized with high buffer capacity during application pH level of the nutrient solution of 4.5 maintained pH of range 6.4-7.1 in the root zone (Dyško et al. 2008). Despite of considerable differentiation of means concentration of mineral nutrient in tomato leaves, the plant growth and development were proper. Concentration of mineral nutrient was comprised at the optimum range of nutritional status of tomato plants.

Note: see Table 1

Fig. 3. The effect of pH of nutrient solution and type of growing medium on the K content in tomato leaves (2004-2006)
Fig. 4. The effect of pH of nutrient solution and type of growing medium on the Ca content in tomato leaves (2004-2006)

Fig. 5. The effect of pH of nutrient solution and type of growing medium on the Mg content in tomato leaves (2004-2006)
Fig. 6. The effect of pH of nutrient solution and type of growing medium on the Fe content in tomato leaves (2004-2006)

Note: see Table 1

Fig. 7. The effect of pH of nutrient solution and type of growing medium on the Mn content in tomato leaves (2004-2006)

Note: see Table 1
CONCLUSIONS

1. The highest total and marketable yield was obtained from tomato plants cultivated in rockwool. For all the growing media, the highest yield of tomatoes was obtained after feeding the plants with the nutrient solutions of pH 5.5.

2. The pH of nutrient solution at the range of 4.5-6.5 did not significantly influence on the nitrogen, potassium and magnesium nutritional status of tomato plants.

3. With an increase of the pH of nutrient solution, the average phosphorus, iron and manganese content in tomato plants was decreased.

4. The higher concentration of nitrogen, calcium and magnesium was proved in leaves of tomato grown in organic substrates than in the rockwool.

5. Plants cultivated in rockwool were characterized with significantly higher phosphorus and manganese concentration than plants growing in organic media.

6. Tomato plants grown in straw contained less potassium and iron but more calcium in comparison to plants cultivated peat.

REFERENCES


WPŁYW ODCZYNU POŻYWKI NA STAN ODŻYWNIENIA I PLONOWANIE POMIDORA UPRAWIANEGO W SYSTEMIE BEZGLEBOWYM

Streszczenie

Celem badań przeprowadzonych w latach 2004-2006 było określenie wpływu zróżnicowanego odczynu pożywki na plonowanie oraz stan odżywienia roślin w bezglebowej uprawie pomidora w podłożach organicznych i inertnym. Uprawę pomidorów prowadzono w matach wykonanych z rozdrobnionej słomy żytniej, w workach z torfem oraz w węłnie mineralnej. Rośliny nawiązano standardowymi roztworami pożywki o zróżnicowanym odczynie pH: 4,5; 5,0; 5,5; 6,0; 6,5. Odczyn stosowanej pożywki jak i rodzaj użytego podłoża miały istotny wpływ na wielkość plonu ogólnego i handlowego pomidora odmiany Blitz F1. Wczesność plonowania nie zależała od odczynu pożywki oraz od rodzaju zastosowanego podłoża. Najwyższy plon ogólny i handlowy stwierdzono w uprawie pomidora w węlnie mineralnej. Porównując odczyn stosowanej pożywki bez względu na rodzaj użytego podłoża najwyższy plon ogólny i handlowy stwierdzono przy pH 5,5. Rodzaj podłoża oraz odczyn stosowanych pożywek istotnie różnicowały stan odżywienia roślin pomidora. Pomimo znacznego zróżnicowania średnich zawartości składników mineralnych w liściach, wzrost i rozwój roślin był prawidłowy, a zawartość składników mieściła się w zakresie optymalnego stanu odżywienia roślin. Odczyn pożywki w zakresie pH 4,5-6,5 nie miał istotnego wpływu na stan odżywienia roślin pomidora azotem, potasem i magnezem. Wraz ze wzrostem pH pożywki, w roślinie istotnie malała średnia zawartość fosforu, żelaza i manganu. W liściach roślin uprawianych w podłożach organicznych stwierdzono wyższą koncentrację azotu, wapnia i magnezu niż w węlnie mineralnej. Rośliny uprawiane w węlnie mineralnej w porównaniu do roślin uprawianych w podłożach organicznych zawierały istotnie więcej fosforu i manganu. Pomidory uprawiane w podłożu wykonanym ze słomy w porównaniu do substratu torfowego zawierały mniej potasu i żelaza, natomiast więcej wapnia.