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Utilisation of nutrients by cucumber plants on rockwool substrate

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Summary: Cucumber production by soil less culture on rockwool substrate in Hungary is an open system regarding its water and nutrient supply. Environmental and economical reasons require the recycling of nutrients of the system. Experiments have been planned in order to estimate the utilisation of individual nutrient elements applied. All around the vegetation period, chemical analyses monitored the depletion of the elements initially administered by sampling the solutions at successive phases from the injection to the overflow. The results have been compared with earlier experiences refering to general rules. It has been stated that the intensity of photosynthesis is decisive in determining the composition of the overflow. The less changes are observed during the period of frequent watering.
The absorption of the nutrient elements varied between 25–51% depending on the individual elements. The differences are significant.
Further examinations are needed in order to clear:
– which are the main elements of technology, which are decisive in utilisation of nutrients
– what are the possibilities of the secondary utilisation of nutrients.

Key words: soil less culture, cucumber, utilisation of nutrient solution

Introduction

Soil less production of vegetables displayed a dynamic development during the last ten years in Hungary. The substrate utilised was variable. Organic substrates based on turf mixtures (*Kappel* et al., 2002) have been rivalled by rockwool because its easy regulation and it In Hungary, the importance of cucumber forcing on rockwool occupies the third position after tomato and pepper. Like other vegetables grown on rockwool, cucumber forcing takes place under plastic cover in a closed system, however, the technology is considered to be open as far as nutrient and water supply have been applied without recycling. From the environmental and economic point of view, a thrifty, i.e. optimal utilisation of water and nutrients should be elaborated, and the losses reduced to a minimum in the future.

Losses of nutrients occur also in traditional cultivation on soil (*Füleky*, 1988; *Tisdale* et al, 1993; *Tóth*. et al) because of washing out, adsorption, and microbiological reduction. Those losses depend on many conditions and are difficult to estimate, moreover, a secondary utilisation of the nutrients cannot be solved.

In the present study, three simultaneously run experiments have been evaluated. The uptake of nutrients has been estimated and compared with the amount of fertilisers administered, thus their utilisation as well as the depletion could be calculated. The initial nutrient solution, the substrate as well the overflow has been analysed throughout the growing cycle in order to does hardly influence the circulation of nutrient.

Material and method

The locations of the experimental production in three farms (I, II, III) are in the Southern Great Plan region *(Table 1)*. They all used rockwool, the system of nutrient solutions needed A–B and acid tanks. Watering and nutrition has been performed by a dripping system.

The water utilised was relatively stable in its composition but from different sources in the three farms (*Rácz*, 2002):

I – desalted well water
II – tap water
III – well water

Table 1 Main data of the farms

Code of farm	Production area (m^2)	Density (pc/m^2)	Variety
I	828	1.48	Suprami
II	2800	1.54	Pedroso F1
III	8000	1.50	Pedroso F1

Nutrient solution has been prepared according to the Dutch standard prescription modified to the chemical composition of the water (*Table 2*, *Szőri*, 1997).

At the time of the first sampling, the production was in progress, fruits grew already on the primary branches and the plots were filled up with nutrients. During the whole growing cycle, monthly once at the same time, samples were taken from the tanks of each farm, and five points from each growing plot (i.e. the average of the five samples has been considered) and from the overflow. Sampling has been timed always to the period, when photosynthesis was on the peak, between 11 and 14 hours.

Date of sampling were: 2004. 03.04.
2004. 04.07.
2004. 05.06.

The sampling was performed by the growers and the analyses at the laboratory of the Department of Chemistry and Soil Science, Tessedik College, Szarvas M.V.K.F.K. for the following parameters: pH, EC (electric conductivity), NO_3–N, P, K, Ca, Mg.

Laboratory tests aimed to reveale regularities of nutrient uptake, and variations in the chemical composition of the overflow.

Under commercial conditions thus all fertilisers containing macro- and meso-elements and acids have been registered as well as the total yield without considering the actual commercial quality.

Results

Table 2 Main characteristics of the water used

Code of farm	pH	EC (mS/cm)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	HCO_3 (mg/l)
I	7.42	0.08	3.1	0.8	13.1	48.2
II	7.41	0.46	49.3	22.9	26.0	369.2
III	6.69	0.66	81.4	28.1	41.4	513.7

Table 3 Yield and nutrient comsumption in the farms

Code of farm	Yield (kg/plant)	N (g/plant)	P (g/plant)	K (g/plant)	Ca (g/plant)	Mg (g/plant)
I	22.8	70.1	15.9	87.8	50.7	9.0
II	18.2	103.4	19.0	137.5	51.9	13.0
III	16.0	86.5	27.9	132.9	44.5	9.6
Avarage:	17.2	90.4	25.7	132.0	47.0	10.6
S	4.1	17.3	8.5	31.0	4.7	2.2

In all cases, average yield means a weighted average of the mass.

S: standard deviation calculated

The data of samples taken on the same day represent averages of the three examined farms (*Fig. 1–7*). The quantity of the nutrients has been expresed as referred to an EC value = 3 mS/cm units.

Discussion of the results

Nutrient consumption of the plants changed during the growing period, continuously. Recommendations of the technology refer to the ratio of nutrients, the proposed acidity (pH) and salt concentration (EC) proper to the respective phenological phase. The amount of nutrients are adjusted to the climatic conditions influencing the rate of transpiration (light, temperature, humidity). The composition of the nutrient solution changes around the roots significantly, which may cause relative or even absolute lack or too high concentrations for individual elements. It is up to the responsibility of the grower to prevent deleterious effects for plant growth. The practice controls the nutrient level of the root zone on the basis of analytical data of the overflow (*Terbe*, 1997). This method is useful exepte its handicap that the parameters of the overflow do not reflect exactly the conditions of the root zone, depending on the watering technology. Most deviations are experienced during the beginning of the growing period, when low amounts of water are administered, and the regulation of growth depends on the ratio of nutrients. Later on, differences between the nutrient solution and the overflow diminish, as uptake of nurients and of water is determined essntially by the itensity of radiation.

Changes in salt content: Current models of plant nutrition are based on the contention that as far as sufficient nutrient elements were available a relatively high salt concentration does not diminish yields. In the case of cucumber, the critical interval in the root zone is between 2–3 mS/cm. Values above this salt concentration are deleterious to yield. EC > 3.3 mS/cm causes 10%, EC > 4.4 mS/cm 25%, EC > 6.5 mS/cm even up to 50% loss of yield (*Göhler & Drews*, 1989). The loss of yield is related to lower osmotic water potential, reduced turgor of the leaves, consequently, slowing down growth of stem, leaves and fruits. On the contrary, root growth is stimulated. As far as salt concentration did not become noxious, the stronger root system may mean increased nutrient uptake, which stimulates photosynthesis under favouable light conditions. In plants, the distribution of the assimilated organic matters depends hardly on the concentration of the root zone, but rather on climatic conditions. A reduced leaf area may favourise the accumulation in the fruits, and increases the dry matter content and quality, respectively. In forcing of vegetables, this observation used to be exploited consciously in order to improve quality during the periods of low light intensity, or when the water utilised containes too much ballast, i.e. useless salt, and an adequate nutrient level is available at higher salt concentration only. In the present experiment, the mentioned tendency was not experienced (*Fig. 1*) as the concentration of the solution did not change much throughout the growing period. The initially high EC values of the plots and of the overflow diminished. In all the three forcing farms and in every case of sampling, EC values of the plots were higher than that of their overflow. The mean difference was 0.34 mS/cm in March, 0.2 mS/cm in April, and 0.05 mS/cm only in May. A significant drop of the difference in the last month is due to frequent watering necessary because of the intense light conditions. In May, nutient solution of higher concentration is administered, which raised the EC of both, the root zone and the overflow.

The correlations experienced prove that a complete automation of the nutrient's concentration cannot be achieved. For finding optimum doses, a monitoring of the overflow values in not sufficient because also additional experiences and the climatic regulation of the greenhouse are necessary.

Changes of pH values in the nutritive solution: In soil less growing cultures, the pH values of the root zone is a decisive condition. High pH values cause deficiency symptoms for individual elements (e.g. Mn, Fe, Zn) because of inhibition of uptake. Nutritive solutions administered affect very little the pH of the root zone and the overflow. The activity of the plant is much more decisive as the selecdtive uptake of cations and anions may exert changes in the pH of the root zone as well as in the overflow. Lower values (4.5–5) of pH are favourable for yield, but its lower buffering capacity, higher (pH = 5–6) values are recommended. In the present experiment, samples were taken at a distance of 10 cm from the plant's base, i.e. active root zone (*Fig. 2*). At a relatively stable pH = 5.5 of the nutritive solution an increase of 0.5 in the root zone and 0.7 in the overflow was stated. Most variation was found (0.8–1.5 units) in plots, where the water used was poor in hidrocarbonates (in farm I). In the two other farms (II and III), hidracarbonate content was regulated by acid treatment, and so the variation did not exceed 0.4–0.8 units.

Changes of the main nutritive elements of the solution: Out of the elements measured, N, P, K, Ca, Mg, the first three varied the most in the plots as well as in the overflow. Calcium and magnesium proved to be relatively abundant in the solution since the beginning and kept to be so throughout in the substrate.

Most uniform dosage was given in nitrogen (*Fig. 3*). The first two sampling witnessed a reduction of 10 and 20% in the plots and the overflow, respectively. In May, however, the amounts of nutrients were more evenly distributed, because either the summer climate or the aging of the plants reduced the requirement of nitrogen.

Phosphorus supply was optimal during March (*Fig. 4*). Later its level dropped in relation to the solution, consequently, the alleged optimum, 39 mg/l, was secured by a solution containing 81 mg/l phosphorus.

Potassium was found to be in higher quantity at the first sampling, but later it diminished in both, the plot as well as overflow, substantially (*Fig. 5*). The solution did not follow the requirement of the plants, as the difference in potassium content between the solution and the samples taken from the plots reached a level of 32%.

Calcium displayed the highest variation in the nutritive solution (*Fig. 6*). The administered Ca dropped by 30%, whereas its presence was enhanced in the plots as well as in the overflow. In May, 20% difference was experienced. It was stated that Ca content was higher (or equal) in the overflow than in the root zone, which may be explained by an easy washing out of this element.

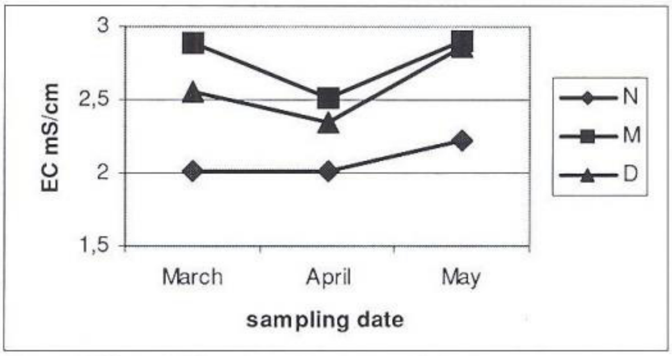

Figure 1 Effect of different sampling dates on EC values

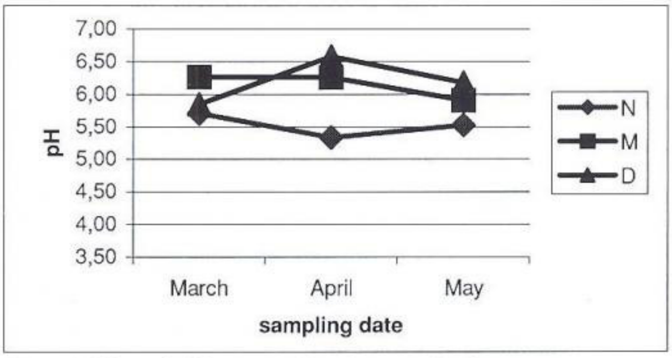

Figure 2 Effect of different sampling dates on pH velues

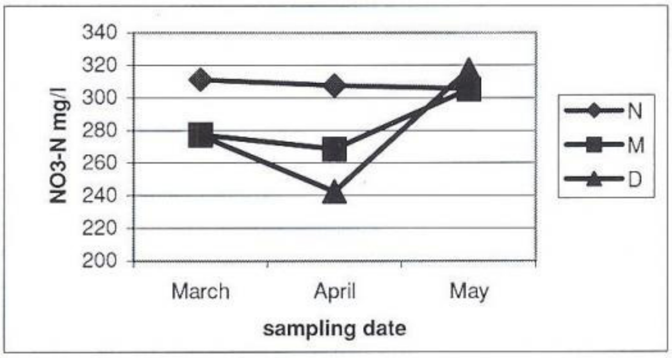

Figure 3 Utilisation of N–NO3 in cucumber production on rockwool

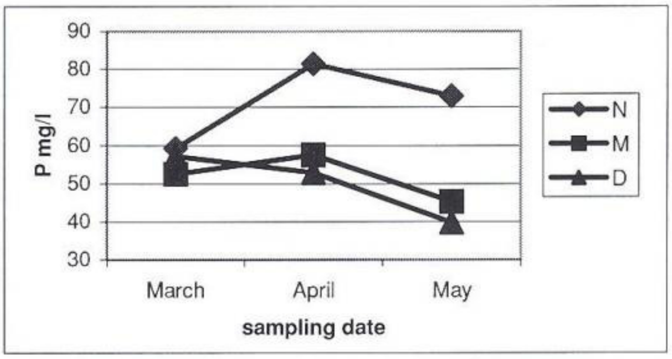

Figure 4 Utilisation of P in cucumber production in rockwool

Magnesium proved to be the most stable element, being more abundant in the plots and the overflow by 20–24% than in the nutritive solution (*Fig. 7*).

The utilisation of nutrients: In our experiment with cucumber grown on rockwool substrate, we refer to the data published by Geissler (1976), which is reproduced in *Table 4*:

Table 4 Nutrient uptake of forced cucumber, g/plant after Geissler (1976)

Yield (kg/plant)	Foliage (kg/plant)	N (g/plant)	P (g/plant)	K (g/plant)	Ca (g/plant)	Mg (g/plant)
30	7.2	42	11.0	67	34	5.9
25	6.0	36	9.2	58	30	5.1
20	4.8	30	7.4	49	26	4.3
15	4.0	23	5.6	40	22	3.5
10	3.2	17	3.8	31	17	2.7

As displayed in *Table 3*, the weighted mean yield was 17.2 kg/plant. The nutrient absorption to produce this amount of yield has been calculated by reiteration based on the contention of a linear regression between the yield and nutrient uptake within the interval of 15 and 20 kg yield. According to the functions describing the changes and recovery of individual elements, the absorption of the elements has been determined (*Table 5*).

Table 5 Utilisation of main nutrient elements in cucumber production experiment on rockwool at an average yield of 17.2 kg/plant

Nutrient element	Total used (g/plant)	Recovery in plants (g/plant)	Overflow (g/plant)	Utilisation (%)
N	90.4	26.1	64.3	29
P	25.7	6.3	19.4	25
K	132.0	44.0	88.0	33
Ca	47.0	24.0	23.0	51
Mg	10.6	3.9	6.7	37

Utilisation %: (Recovery in plants / Total of the administered nutritive).100

The utilisation of the elements shown in *Table 3* varied conspicuously between the three farms.

The less specific utilisation of nutrients, except Calcium, was experienced in farm I, whereas the highest specific utilisation was found in farm II, except for Phosphorus.

The first case of Farm I has been explained by the low Ca content of desalted water used (*Table 2*), because the natural Ca content of the water was not considered in planning the doses.

In Farm III, where the water contained more salt and sodium, it was expected to require higher rates of overflow, consequently, higher consumption of nutrients. On the contrary, Farm II produced that, where the salt and sodium content of the water was relatively low. It should be postulated that, within certain limits, utilisation of nutrients is not only determined by the quality of water used, but also other conditions of the growing facilities are influencing the results.

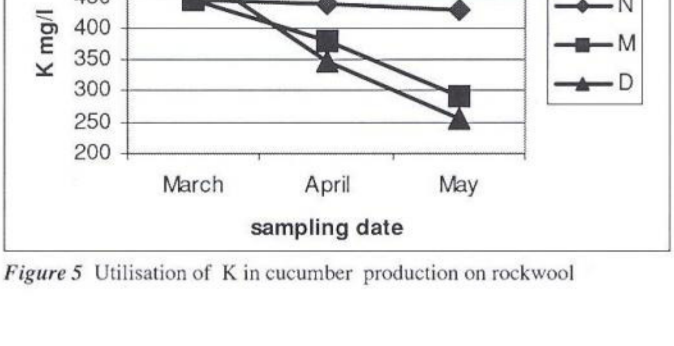

Figure 5 Utilisation of K in cucumber production on rockwool

As for the utilisation of nutrients (*Table 5*), the lowest rates were obtained in Phosphorus, the highest in Calcium. The beneficial effects of Calcium are enhanced by its presence in the water used as an additional source. Altogether, 25–51% of the nutrients administered purposefully in the solution found its way to appear in the yield.

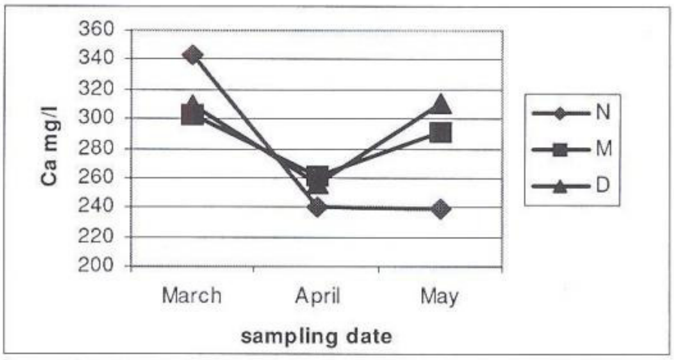

Figure 6 Utilisation of Ca in cucumber production on rockwool

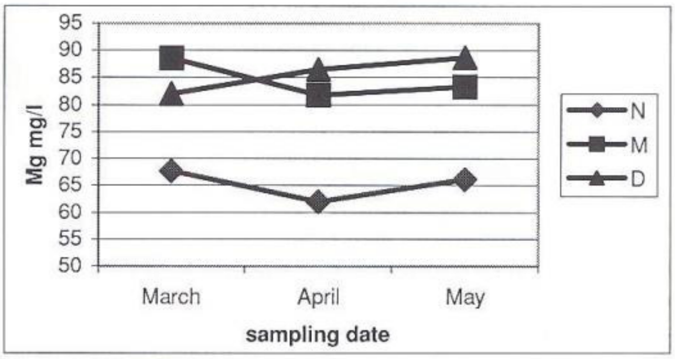

Figure 7 Utilisation of Mg in cucumber production on rockwool

Note: **N** = nutrient solution
M = medium solution
D = drain solution

Conclusions

The differences found between the nutrient composition of the substrate of the root zone and that of the overflow is attributed to the activity of the plant. For the purpose to modify the nutrient solution in order to improve the utilisation of nutrients, the analysis of the composition of the substrate at the root zone gives more information than the composition of the overflow, because in the latter some elements are over-represented and others under-represented in relation to the root zone. The quality of water utilised influences substantially the losses of nutrients. The overflow may containe significant amounts of various nutritive elements, therefore a closed cycle of utilisation or a reutilisation in soils is justified.

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