DETERMINATION OF THE OPTIMAL NITROGEN CONTENT IN A FERTIGATION MEDIUM FOR THE GREENHOUSE CUCUMBER GROWN ON SLABS OF COMPRESSED STRAW

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Summary

In the years 2004-2008, research work was carried out whose aim was to determine the optimal nitrogen fertilization dose for greenhouse cucumbers grown on mats made of compressed, finely shredded straw. In the experiments, the short-fruited variety of the greenhouse cucumber, Milenium F₁, was used. The level of nitrogen in the nutrient solution was varied in the range of 200-350 mg·dm⁻³. The nitrogen content in the solution in the amount of 200 mg·dm⁻³ was not sufficient and caused the cucumber yield to fall. The increasing N concentrations in the medium were found to have a significant effect on the nitrogen content in the indicator parts of cucumber plants. The highest nitrogen content was found in the plants fertilized with a nutrient solution containing the highest concentration of N-NO₃, which was 350 mg·dm⁻³. Cucumber plants grown on straw need to be more intensely fertilized with nitrogen for about 1/3 of the growing season, and then to have its level in the fertigation medium reduced for the remaining part of the cultivation period.

key words: cucumber, fertigation, straw, nitrogen

INTRODUCTION

The drive to reduce production costs and the difficulties in obtaining farm-yard manure have caused the technology of growing popular greenhouse vegetable species, such as the cucumber, to undergo considerable changes. Depending on the kind of the cultivation technology used, the fertilization requirements of the cucumber may differ substantially. A significant effect on the size of the cucumber yield has nitrogen. In field cultivation, the optimum nitrogen content is specified by Al-Jaloud *et al.* (2006) to be in the range of 150 to 200 mg·dm⁻³, depending on the concentration of other macro-elements in the soil. In field cultivation, the nitrogen content in the nutrient solution is adjusted according to the way in which fertilization is carried out. The highest yields of the greenhouse cucumber in field cultivation were obtained by Güler *et al.* (2006) as

a result of using a nutrient solution containing $200 \text{ mg N} \cdot \text{dm}^{-3}$ twice a week and continuing this supplementary feeding until the soil water potential at a depth of 30 cm had reached the value of 30 kPa. For cucumber plants the form of the nitrogen used in supplementary feeding is also important. Higher levels of ammonium nitrogen reduced yields and fruit quality of a crop grown on mineral wool. The optimal fertilization during the spring and winter seasons was the use a fertigation solution containing $100 \text{ mg N} \cdot \text{dm}^{-3}$ in the nitrate form (Kotsiras *et al.* 2005). When crops are to be grown on perlite, it is recommended that the nitrogen content in the nutrient solution should not exceed $200 \text{ mg} \cdot \text{dm}^{-3}$. It has been demonstrated that the use of a fertigation medium in which the nitrogen concentration was $300 \text{ mg} \cdot \text{dm}^{-3}$ caused the cucumber yield to fall (Altunlu *et al.* 1999). The efficiency of nitrogen utilization depends also on the way in which the plants are being supplied with supplementary nutrients. In the case of the cucumber, fertigation is a more effective means than soil-applied fertilization (Al-Wabel *et al.* 2006). Organic substrates provide good conditions for many microorganisms to thrive in, which for their own development absorb considerable amounts of nitrogen, thus reducing the amount of this element available to plants. This has been confirmed by the studies of Kowalczyk and Dyśko (2006), who, while growing tomatoes on rye straw, found low levels of nitrogen during the first weeks of cultivation. In relation to cultures carried out on mineral wool, Babik (2006) recommends to increase the nitrogen content in the nutrient solution by 20%.

MATERIALS AND METHODS

In 2004-2008, experiments were carried out whose aim was to determine the optimum fertilization with nitrogen of greenhouse cucumbers grown on mats made of compressed, finely shredded straw. The straw, cut up into 0.5 cm lengths, was compressed under a pressure of 0.3 MPa and shaped into slabs measuring $100 \times 20 \times 10 \text{ cm}$. During the pressing stage, the slabs were placed in semi-opaque whitish plastic bags. The control combination was a crop grown on mineral wool, fertilized in a conventional way. Irrigation combined with fertilization was carried out at 1-2 hour intervals, depending on the needs of the plants, the climatic conditions and moisture content in the substrate. The irrigation systems were equipped in Dosatron proportional liquid dispensers for fertilizers. The maximum daily (24 hrs) nutrient dosage during the peak period of plant growth and spells of high temperatures was as much as 4 litres per plant.

In the experiments use was made of the short-fruited variety of the greenhouse cucumber Milenium F₁. In the last year of the study, a different method of training the plants was used, which involved 1 runner with all the lateral runners removed. When the plants had reached the top of the supporting structure, they were lowered, the way tomato plants are trained. Also, the Milenium F₁ cultivar was replaced with Pacto F₁. Each experimental plot consisted of 8 slabs, with 2 plants per slab. The total surface area of a plot was 3.8 m^2 . Each experiment was set up in a one-factorial system with 6 replications. The nitrogen content of the nutrient solution was maintained at the levels of: 200, 250, 300 and 350 mg

$\text{N-NO}_3\cdot\text{dm}^{-3}$. From 2006, the nitrogen concentration of $350\text{ mg}\cdot\text{dm}^{-3}$ was maintained in the fertigation medium for only about 1/3 of the growing period, and after that time the amount of nitrogen was reduced to $250\text{ mg N-NO}_3\cdot\text{dm}^{-3}$. The levels of other minerals in the nutrient solution for all the fertilization combinations were as follows: $53\text{-}54\text{ mg}\cdot\text{dm}^{-3}$ P, $300\text{-}309\text{ mg}\cdot\text{dm}^{-3}$ K, $59\text{-}60\text{ mg}\cdot\text{dm}^{-3}$ Mg, $151\text{-}178\text{ mg}\cdot\text{dm}^{-3}$ Ca. The levels of micro-elements in the fertigation medium ($\text{mg}\cdot\text{dm}^{-3}$) were as follows: 1.9 - Fe, 0.72 - Mn, 0.27 - B, 0.13 - Cu, 0.13 - Zn, and 0.04 Mo. During plant growth, chemical analyses of the nutrient solution taken from the substrate were carried out on a regular basis. The solutions from growth mats were collected into containers placed under the mats at 2-weekly intervals. The solutions were analysed in terms of pH, salinity, and the levels of the basic nutrients: N-NO_3 , N-NH_4 , P, and K. Nitrogen was determined colorimetrically with a Skalar SanPlus automated flow analyzer, and phosphorus and potassium with a Perkin Elmer OPTIMA 2000 DV plasma spectrometer.

After drying at a temp. of 65°C , the plant material was ground and subjected to mineralization in concentrated nitric acid in a Candela Mars 5 microwave digestion oven. Phosphorus and potassium were determined with the plasma spectrometer, like the solutions from the growth mats. Total nitrogen was determined with the Kjeldahl method.

Cucumbers were harvested regularly and the growth dynamics, early yield, marketable yield and total yield were determined. The early yield was assumed to be made up of the fruits collected during 1/3 of the entire harvesting period.

The statistical analysis of the obtained results was performed by means of the programme Statistica using the ANOVA/MANOVA analysis and the Newman-Keuls test at a significance level of $P=0.05$.

RESULTS AND DISCUSSION

The experiments conducted in 2004 and 2005 aimed at determining the optimal nitrogen content in the solution used for fertigation of cucumber plants grown in a greenhouse on mats made of compressed straw. The nitrogen content was maintained at the same level throughout the entire growing period. Only a week before the last harvest the plants were irrigated with water only.

Table 1. Dates on which the more important activities were carried out in 2004-2008

Activity	2004	2005	2006	2007	2008
Pre-sprouting of seeds	26.02	24.02	27.02	27.02	3.03
Sowing of seeds	27.02	25.02	28.02	1.03	4.03
Planting of seedlings in pots	8.03	8.03	13.03	9.03	12.03
Planting of cucumber plants in greenhouse	26.03	29.03	3.04	30.03	7.04
First harvest	19.04	21.04	28.04	23.04	28.04
End of harvesting	29.07	25.07	28.07	19.07	28.07

The increase in nitrogen content in the nutrient medium had a beneficial effect on the size of the early yield of the cucumber fruits cv. Milenium F₁. The nitrogen content of $200\text{ mg}\cdot\text{dm}^{-3}$ in the solution, which is the maximum value

for cucumber crops grown in the field (Güler 2006), was insufficient and caused a significant drop in the early yield. For the sake of earliness in fruiting, maintaining nitrogen (N-NO_3) at the highest level of $350 \text{ mg}\cdot\text{dm}^{-3}$ proved to be the most advantageous. The same relationship existed in 2004 and 2005 (Fig. 1). This level of nitrogen for crops grown on inert substrates such as perlite is too high and results in a reduced fruit yield (Altunlu *et al.* 1999). The statistical analysis carried out in a system with repeatable measurements showed that by increasing nitrogen content from 250 to $350 \text{ mg N-NO}_3\cdot\text{dm}^{-3}$ a gradual increase in the early yield was achieved, although the differences between the yield values were not significant. Fertilization of plants grown on mineral wool employed a nutrient medium containing $250 \text{ mg N-NO}_3\cdot\text{dm}^{-3}$. The early yields obtained from the plants grown on mineral wool and on straw supplied with a solution containing $250 \text{ mg N-NO}_3\cdot\text{dm}^{-3}$ were similar (Table 2).

Fig. 1. Effect of different nitrogen content in the nutrient solution on the early yield of cucumber in 2004 and 2005

Table 2. Effect of nitrogen content in the nutrient solution on the yields of cucumber cv. Milenium F₁ (mean values for 2004-2005, system with repeatable measurements)

Nitrogen (N-NO_3) content ($\text{mg}\cdot\text{dm}^{-3}$)	Yield ($\text{kg}\cdot\text{m}^{-2}$)		
	early	marketable	total
200	7.69 b	29.6 a	30.3 a
250	9.29 a	31.7 a	32.2 a
300	9.38 a	30.9 a	31.4 a
350	9.69 a	30.0 a	30.6 a
Control – rock wool	9.16 ab	30.6 a	31.5 a

Note: Mean values followed by the same letter within a column are not significantly different at $P=0.05$

As the process of straw mineralization intensified, the amount of available nitrogen gradually increased (Fig. 2). As a result, the highest marketable and total yields were obtained at the nitrogen content of $250 \text{ mg N-NO}_3\cdot\text{dm}^{-3}$. Higher levels of nitrogen, i.e. 300 and $350 \text{ mg N-NO}_3\cdot\text{dm}^{-3}$, were unfavourable since they caused a drop in the marketable and total yields (Table 2). The analysis of yield dynamics in 2005 showed that the use of high nitrogen fertilization rates ($350 \text{ mg}\cdot\text{dm}^{-3}$) was advantageous only until the 11th harvest (Fig. 3). This length of time coincided exactly with the period in which the early crop was harvested. These results were the reason why changes were introduced in 2006, which consisted in using for fertigation a medium containing $350 \text{ mg}\cdot\text{dm}^{-3}$ for only $1/3$ of the growing period and later with a nitrogen content reduced to $250 \text{ mg}\cdot\text{dm}^{-3}$. This fertilization combination proved to be the most advantageous for the cucumber grown on straw. As a result, a significant increase in the early yield was obtained. The varied N levels in the nutrient solution did not have any effect on the size of the early yield in 2008 because of poor insolation in the spring. The beneficial effect of fertigation with a medium containing nitrogen at $350 \text{ mg N-NO}_3\cdot\text{dm}^{-3}$, and later at $250 \text{ mg}\cdot\text{dm}^{-3}$ is also confirmed by the analysis of multi-year averages (Table 3). Good yields were also obtained from cucumber plants grown on mineral wool.

Fig. 2. Changes in N-NO_3 content in drainage waters flowing out of the straw substrate during plant growth in 2005 depending on different nitrogen fertilization doses – 200 , 250 , 300 , and $350 \text{ mg}\cdot\text{dm}^{-3}$

Fig. 3. Cucumber yield dynamics in 2005 – differences between the yields obtained at the nitrogen content in the medium of $350 \text{ mg} \cdot \text{dm}^{-3}$ and the yields of cucumber plants fertilized with a solution containing nitrogen at 250 and $300 \text{ mg} \cdot \text{dm}^{-3}$

Table 3. Effect of various nitrogen content (N-NO_3) in the nutrient solution on cucumber yields in 2006-2008 ($\text{kg} \cdot \text{m}^{-2}$)

N content in medium ($\text{mg} \cdot \text{dm}^{-3}$)	2006	2007	2008	Three-year average
Early yield				
200	10.17b	8.19b	8.03b	8.80c
250	10.30b	8.29b	8.43b	9.00c
300	10.85b	8.01b	7.60b	8.82c
350/250	11.81a	8.57ab	8.13b	9.50b
Control	10.67b	9.06a	10.55a	10.09a
Marketable yield				
200	34.02b	28.42a	26.46b	29.63
250	34.47b	27.20ab	26.43b	29.36
300	34.33b	27.25ab	24.38b	28.65
350/250	36.05a	27.02ab	24.54b	29.20
Control	35.39ab	25.22b	29.16a	29.92
Total yield				
200	35.26	28.60a	26.74b	30.20
250	35.87	27.47ab	26.83b	30.06
300	35.78	27.45ab	24.65b	29.29
350/250	37.31	27.15ab	24.98b	29.82
Control	36.72	25.39b	29.53a	30.55

Note: see Table 2

In the latter part of the growing period the differences in yield gradually disappeared. Apart from the nutrient solution, the decomposing straw was becoming increasingly important as a source of nitrogen for the plants (Fig. 4). A significantly higher yield attributed to the use of a medium containing nitrogen at $350 \text{ mg N-NO}_3\cdot\text{dm}^{-3}$, and later at $250 \text{ mg}\cdot\text{dm}^{-3}$, persisted for the marketable yield in 2006 only (Table 3).

Fig. 4. Changes in N-NO₃ content in drainage waters during plant growth depending on the nitrogen content in the nutrient medium associated with the different rates of nitrogen fertilization – 200, 250, 300, and 350 mg·dm⁻³ (2007)

The chemical analyses carried out during the plant growing period revealed that the pH value in the straw substrate did not fall below 7.0 and was significantly higher than in mineral wool (Table 4). The use of varied amounts of nitrogen in the nutrient solution supplied to the plants had resulted in significant changes in the concentration of both N-NO₃ and N-NH₄ in the growth mats. Increasing the N concentration in the fertigation medium from 200 to 300 mg·dm⁻³ did not have a significant effect on the N-NO₃ content in the mats. It was only after the dosage of 350 mg N·dm⁻³ had been applied that a significant increase in N concentration could be seen in the root environment. Fertilization with a solution containing 200 and 250 mg N per litre did not affect the N-NH₄ content in the growth mats. It was only the higher N concentrations, i.e. 300 and 350 mg·dm⁻³, that produced a significant increase in the N-NH₄ content in the mats. A similar trend was observed for the total amount of salt represented by the EC value. Phosphorus and potassium content remained at the same, constant level in all the experimental plots. Nurzyński (2006), while carrying out experiments with tomato crops grown on ecological substrates, found no significant differences in the yields produced, nor in the nutritional status of plants grown on mineral wool and a straw substrate. The author is of the opinion that

there is no need to adjust the composition of the nutrient solution during plant growth, but the results of our experiments with cucumber crops grown on straw indicate the necessity for introducing an adjustment to the nitrogen content in the nutrient solution because of the changes in the levels of this element in the substrate as a consequence of the mineralization of the substrate produced by soil micro-organisms.

Table 4. Effect of different nitrogen concentrations in the nutrient solution on pH, total salt concentration and the levels of basic nutrients in the root growth environment in the cultivation of greenhouse cucumber on straw.

N conc. (mg·dm ⁻³)	pH	EC	N-NO ₃	N-NH ₄	P- PO ₄	K
		mS cm ⁻¹	mg·dm ⁻³			
200	7.46 a	3.01 d	76.8 c	6.12 c	33.5	498
250	7.30 a	3.18 cd	89.5 c	10.6 c	31.7	442
300	7.56 a	3.49 bc	119 c	27.4 ab	36.4	468
350	7.38 a	4.07 a	198 b	39.3 ab	41.7	529
Control	6.40 b	3.74 ab	252 a	20.0 bc	44.6	398

Note: see Table 2

The results of the analyses of the plant material showed that the nutritional status of the plants with respect to the basic nutrients was satisfactory (Table 5). The increasing N concentrations were found to have a significant effect on the N content in the indicator parts of the plants. The highest N content was in the plants fertilized with a fertigation medium containing the highest concentration of N-NO₃ at 350 mg·dm⁻³.

Table 5. Effect of different nitrogen concentrations in the nutrient solution on the levels of basic nutrients in the leaves of cucumber plants grown on straw

N conc. (mg·dm ⁻³)	N	P	K
	% DW		
200	4.28 c	0.32	4.08
250	4.39 bc	0.30	3.73
300	4.75 a	0.32	3.95
350	4.79 a	0.31	4.07
Control	4.64 ab	0.27	3.95

Note: see Table 2

CONCLUSIONS

1. Greenhouse cucumber crops grown on straw required higher rates of nitrogen fertilization for about 1/3 of the growing period. The optimum nitrogen content in the nutrient solution during that time was 350 mg N-NO₃·dm⁻³.
2. Following the harvest of the early crop, the amount of the available nitrogen increased as a result of straw mineralization, so there was a need to reduce the amount of that element in the nutrient solution to 250 mg N-NO₃·dm⁻³.

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OKREŚLENIE OPTYMALNEJ ZAWARTOŚCI AZOTU W POŻYWCIE
WYKORZYSTYWANEJ DO FERTYGACJI OGÓRKA SZKLARNIOWEGO
UPRAWIANEGO NA PŁYTACH SPRASOWANEJ SŁOMY

Streszczenie

W latach 2004-2008 prowadzono badania, mające na celu określenie optymalnego nawożenia azotem ogórków szklarniowych, uprawianych na sprasowanych matkach, wykonanych z drobno rozdrobnionej słomy. W doświadczeniu wykorzystano krótkoowocową odmianę ogórka szklarniowego Milenium F₁. Poziom azotu w pożywce dozowanej różnicowano w zakresie od 200 do 350 mg dm⁻³. Zawartość azotu w pożywce w ilości 200 mg dm⁻³ była niewystarczająca i powodowała spadek plonu ogórka. Stwierdzono istotny wpływ wzrastających stężeń N w pożywce na zawartość azotu w częściach wskaźnikowych roślin. Zawartość azotu była najwyższa u roślin nawożonych pożywką o najwyższym stężeniu N-NO₃, wynoszącym 350 mg dm⁻³. Uprawa ogórków na słomie wymaga intensywniejszego nawożenia azotem przez około 1/3 okresu wegetacji, a w dalszej części uprawy obniżenia jego poziomu w pożywce do fertygacji.