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EFFECT OF NUTRIENT SOLUTION CONCENTRATION ON YIELD AND QUALITY OF GERBERA GROWN IN PERLITE

Włodzimierz Breś, Agata Kozłowska, Tobiasz Walczak

Chair of Plant Nutrition
Poznan University of Life Sciences

Abstract

The aim of the experiments was to achieve a reduction in the concentration of a nutrient solution used for fertigation of miniature gerbera grown in perlite. During the first 4 weeks after the planting of gerberas, the nutrient solution used for fertigation had a concentration of 1.4 mS cm^{-1}. Next, half of the plants were nourished with the standard nutrient (EC 2.0 ± 10% mS cm^{-1}) while the other half received a more dissolved solution (EC 1.6 ± 10% mS cm^{-1}). The overflow was set at 25% of the daily applied nutrient solution. The number of flowers, the diameter of flower heads and the length of peduncle were not affected by a 20% decrease in the concentration of nutrient solution. The nutritional status of gerbera was also satisfactory. The concentrations of most ions in the leakage were slightly higher than in the nutrient solutions applied for fertigation. The results indicate that the application of solutions with a lower EC did not cause any drastic changes in the plant root environment. The study showed that it is possible to use about 20% less of fertilizers without any negative effects on the number and quality of gerbera flowers grown in perlite. Similar studies should be performed to analyze potential savings of fertilizer in the cultivation of other plant species. The results could contribute to lesser environmental pollution.

Key words: fertilization, soil pollution, drainage waters, root environment.

prof. dr hab. Włodzimierz Breś, Chair of Plant Nutrition, Poznan University of Life Sciences, Zgorzelecka 4, 60-198 Poznan, Poland, e-mail: wbnaw@up.poznan.pl

WPŁYW STĘŻENIA POŻYWKI NA PLON I JAKOŚĆ GERBERY UPRAWIANEJ W PERLICIE

Abstrakt

Celem pracy było zbadanie możliwości zmniejszenia stężenia pożywki stosowanej do fertygacji miniaturowych odmian gerbery uprawianych w perlicie. Przez pierwsze cztery tygodnie po posadzeniu do fertygacji wszystkich roślin stosowano pożywkę o stężeniu 1.4 mS cm^{-1}. Następnie połowę roślin żywiono pożywką standardową (EC 2,0 ± 10% mS cm^{-1}), natomiast pozostałe rośliny pożywką o stężeniu 1,6 ± 10% mS cm^{-1}. Dzienny przelew ustalono na poziomie 25%. Obniżenie EC pożywki o ok. 20% nie wpłynęło na liczbę wytworzonych kwiatów, średnicę kwiatostanów i długość szypuły gerbery. Stan odżywienia roślin mieścił się w zakresie optymalnym. Stężenie większości jonów w pożywce wyciekającej z podłoża było nieznacznie wyższe niż stężenie pożywki dostarczanej roślinom. Wykazano, że zastosowanie roztworów o niższym EC nie spowodowało drastycznych zmian w środowisku korzeniowym roślin, a także jest możliwe ograniczenie zużycia nawozów o ok. 20% bez negatywnego wpływu na liczbę i jakość kwiatów gerbery uprawianej w perlicie. Wyniki wskazują na potrzebę wykonania podobnych badań w celu ograniczenie zużycia nawozów podczas uprawy innych gatunków roślin. Może się to przyczynić do zmniejszenia zanieczyszczenia środowiska glebowego.

Słowa kluczowe: nawożenie, zanieczyszczenie gleby, wycieki, środowisko korzeniowe.

INTRODUCTION

Soilless cultures and fertigation are the base of modern horticultural technologies. Most of them are open system technologies, where any excess of the applied nutrient solution exudes from the substrate to the soil. In order to stabilize the concentration and pH of the solution in the root zone and to adjust the substrate moisture, the volume of nutrient solution must be higher than the nutritional requirements of the plants (De Pascale, Paradiso 2001). Currently, 25-50% of overflow is recommended for soiless culture (Van Os 1995, Kläring 2001, Brajeul 2005). This leads to an uncontrollable leakage of concentrated nutrient solutions to the soil and then to the ground or surface waters. Thus, greenhouse fertigation causes severe environmental pollution, which has been confirmed by studies carried out in the Netherlands (Van Os 1999), in Italy (De Pascale, Paradiso, 2001), in Spain (Thompson et al. 2002) and in Poland (Breś 2009).

In view of the costs of fertilizers and the negative influence of open fertigation systems on the environment, studies have been undertaken aiming at limiting the doses of applied fertilizers. It has been accepted that successful culture must be carried out in a completely inert medium, which does not modify or only slightly modifies the chemical composition of nutrient solution during plant cultivation. This condition is not met by rockwool, especially at the beginning of plant cultivation, as it alkalizes solutions. Perlite is a fully inert medium. Furthermore, solutions percolate through perlite faster than through rockwool. Thus, the fertigation frequency cannot be decreased, but the concentration of nutrient solution could be lowered. The effect of a lower nutrient solution concentration was investigated in an experiment on miniature gerbera cultivated in perlite.

MATERIAL AND METHODS

Two cultivars of the miniature *Gerbera jamesonii* Bolus were grown in the experiment: Cafe® and Kimsey®, both from the Schreurs breeding nursery. On 8 April 2009, single plants were planted in 3.5 dm^3 containers (with holes in the bottom) filled with perlite. The containers were placed on benches (150 containers with one cultivar in each row; 6.5 containers m^{-2}). An automatic fertilizer mixer and a drip irrigation system for fertigation were applied. During the first 4 weeks after planting, the nutrient solution concentration of 1.4 mS cm^{-1} was used for fertigation. Next, half of the plants were nourished with the standard nutrient (EC 2.0 ± 10% mS cm^{-1}) while the other half of plants received a more dissolved solution (EC 1.6 ± 10% mS cm^{-1}). Taking into consideration the age of plants, stage of plant development and weather conditions, the concentration of some nutrients was slightly higher in the second year of gerbera culture than in the first year. This is consistent with the model suggesting that concentration of a nutrient solution is adaptable to the climatic conditions in a greenhouse i.e. e.g. increased solar radiation necessitates a decrease in the EC of a (KLÄRING, CIERPINSKI 1998, KLÄRING 2001). The insolation during the growing seasons in 2009 and 2010 is illustrated in Figure 1. The chemical composition of nutrient solutions supplied though drips to plants is specified in Tables 1 and 2.

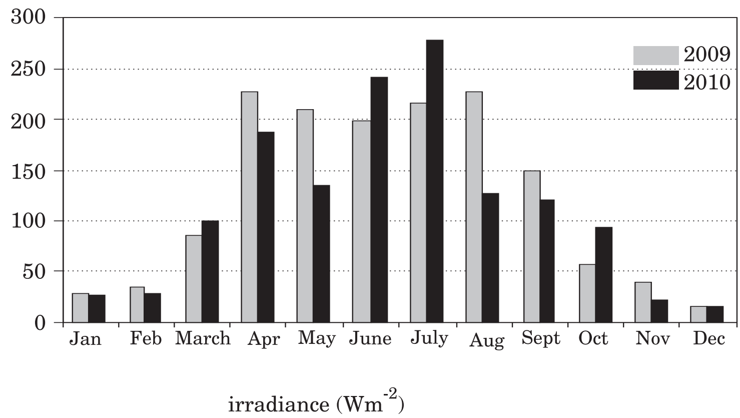

Fig. 1. Insolation during the experiment

Table 1

The nutrient concentration, electrolytic conductivity and pH of the nutrient solution during cultivation of gerberas in 2009 (mean values)

Place of sampling	N- NH_4	N-NO_3	P	K	Ca	Mg	Na	Cl	S-SO_4	Fe	Mn	Zn	Cu	B	EC (mS cm^{-1})	pH
($mg\ dm^{-3}$)																
Cafe																
EC 1.6 ($mS\ cm^{-1}$)																
Drip	1.7	120.5	38.4	194.9	106.4	39.8	27.6	32.4	50.0	1.73	0.71	0.37	0.10	0.19	1.68	6.09
Leakage	1.1	124.9	39.5	196.9	113.3	45.7	37.6	34.8	55.8	1.88	0.57	0.46	0.13	0.20	1.81	6.33
Change (%)*	65	104	103	101	107	115	136	107	112	109	80	124	130	105	108	–
EC 2.0 ($mS\ cm^{-1}$)																
Drip	1.9	167.7	54.8	297.1	125.9	49.1	35.4	36.2	61.1	2.73	1.04	0.54	0.17	0.24	2.19	5.96
Leakage	1.2	172.7	56.0	299.7	137.6	54.6	48.8	38.6	66.6	2.73	0.96	0.67	0.20	0.24	2.37	6.13
Change (%)*	63	103	102	101	109	111	138	107	109	100	92	124	118	100	108	–
Kimsey																
EC 1.6 ($mS\ cm^{-1}$)																
Drip	1.7	120.5	38.4	194.9	106.4	39.8	27.6	32.4	50	1.73	0.71	0.37	0.1	0.19	1.68	6.09
Leakage	1.2	123	38.7	173.3	116.8	46.7	36.5	34.3	54.5	1.98	0.45	0.48	0.14	0.20	1.75	6.47
Change (%)*	71	102	101	89	110	117	132	106	109	115	64	130	140	105	104	–
EC 2.0 ($mS\ cm^{-1}$)																
Drip	1.9	167.7	54.8	297.1	125.9	49.1	35.4	36.2	61.1	2.73	1.04	0.54	0.17	0.24	2.19	5.96
Leakage	1.6	174.1	55.6	268.8	139.6	56.3	46.6	28.2	65.2	2.87	0.9	0.71	0.24	0.25	2.34	6.22
Change (%)*	84	104	102	91	111	115	132	1065	107	105	87	132	141	104	107	–

* modification of nutrient concentrations in leakage in relation to the drip

Table 2

The nutrient concentration, electrolytic conductivity and pH of the nutrient solution during cultivation of gerberas in 2010 (mean values)

Place of sampling	N- NH_4	N-NO_3	P	K	Ca	Mg	Na	Cl	S-SO_4	Fe	Mn	Zn	Cu	B	EC (mS cm^{-1})	pH
(mg dm^{-3})																
Cafe																
EC 1.6 (mS cm^{-1})																
Drip	1.0	146.2	59.1	251.6	103.4	31.2	24.8	27.7	68.1	3.27	0.79	0.27	0.09	0.22	1.79	5.87
Leakage	1.0	168.6	66.8	288.6	110.5	41.5	41.3	30.7	77.5	4.82	0.77	0.37	0.14	0.24	2.07	6.14
Change (%)*	100	116	113	115	107	133	167	112	114	147	98	137	156	109	116	–
EC 2.0 (mS cm^{-1})																
Drip	0.7	177.3	67.4	330.4	109.5	41.0	32.0	30.2	74.3	5.58	0.98	0.37	0.13	0.25	2.23	5.95
Leakage	1.4	207.7	69.4	358.3	120.2	52.4	51.8	33.9	90.2	6.26	0.96	0.51	0.19	0.28	2.54	6.03
Change (%)*	200	117	103	108	110	128	162	112	122	112	98	138	146	112	114	–
Kimsey																
EC 1.6 (mS cm^{-1})																
Drip	1.0	146.2	59.1	251.6	103.4	31.2	24.8	27.7	68.1	3.27	0.79	0.27	0.09	0.22	1.79	5.87
Leakage	1.1	163.3	64.8	258.3	114.5	40.9	38.5	30.3	77.9	4.12	0.82	0.36	0.15	0.24	1.98	6.23
Change (%)*	110	112	110	103	111	131	155	109	114	126	103	133	167	109	111	–
EC 2.0 (mS cm^{-1})																
Drip	0.7	177.3	67.4	330.4	109.5	41.0	32.0	30.2	74.3	5.58	0.98	0.37	0.13	0.25	2.23	5.95
Leakage	0.8	202.3	68.5	322.9	118.6	49.5	45.2	33.0	82.0	5.83	1.06	0.48	0.18	0.27	2.35	6.09
Change (%)*	114	114	102	98	108	121	141	109	112	104	108	130	139	108	105	–

* modification of nutrient concentrations in leakage in relation to the drip

The nutrient solutions were prepared from multi-compound fertilizers (Effect 16-16-8, Effect 5-20-30), calcium saltpeter, magnesium saltpeter and nitric acid. The fertigation frequency was similar for all the plants, ranging from one application per day in winter to seven applications on very hot summer days, each treatment consisting of 100 cm^3. The overflow in the open system was set at 25% of the daily applied nutrient solution. The solution did not remain stagnant in the container as the whole excess leaked through holes in the bottom of containers into the soil.

For biomorphological measurements, 12 plants from each treatment were randomly selected. In 2009, starting with the first harvest (i.e. from 1 June to 31 October), flowers collected from each plant were counted. Also, the flower stems and diameters of flower heads were recorded. Similar measurements were carried out in 2010, from 1 April to 30 June. Samples of fully developed leaves were taken for chemical analyses on 15 June, 15 August and on 15 October in 2009 and on 15 April and 15 June in 2010. The total content of macro- and microelements was determined in dried plant material after its mineralization in strong acids. The total N was determined by the Kjeldahl's procedure. The concentrations of K, Ca, Mg, Fe, Mn, Zn and Cu were determined in an atomic absorption spectrophotometer. Spectrophotometric methods were applied for determination of the P content. Samples of the nutrient solution leaking out from the drips and from the perlite were collected in the middle of each month, during the flower harvest. The concentrations of the following ions were measured: $N\text{-}NH_4$, $N\text{-}NO_3$, P, K, Ca, Mg, Na, Cl, $S\text{-}SO_4$, Fe, Mn, Zn, Cu and B. Furthermore, the pH value and electrolytic conductivity (EC) were determined. The above analytic methods were applied to all elements except nitrogen, sodium, sulphur, chlorides and boron. $N\text{-}NH_4$ and $N\text{-}NO_3$ were determined with the distillation method designed by Bremner and modified by Starck, Na was assayed in an atomic absorption spectrophotometer, while S and Cl were assessed nephelometrically and B was checked by spectrophotometry. The results of biomorphological measurements were evaluated using analysis of variance and the LSD was calculated at $p = 0.05$.

RESULTS AND DISCUSSION

In commercial horticulture, nutrient solution is adapted to specific plant species, the growth and development stage of plants and to the course of climatic conditions. It is a widespread practice to use the same nutrient solution for plant cultivation in an inert medium as a basic solution, ignoring the specific properties of these media. At first, the recommendations elaborated by Sonneveld and Straver (1989) were commonly followed for growing gerbera in inert media, although the nutrient solutions they recommended were designed for plant cultivation in rockwool. The electrolytic conductivity of these solutions was 1.7 mS cm^{-1}. After a few years, some modifications were made, especially for plants grown in a multi-component medium. PARADISO et al. (2003) grew gerbera in a mixture of peat and perlite (1:1) and studied the suitability of nutrient solutions in concentrations of 1.6 and 2.4 mS cm^{-1}. The number of harvested flowers from one plant treated with a higher EC was 10% bigger. However, during the 8-month period, the daily water uptake was also higher in plants fertilized with the more concentrated nutrient solution. ZHENG et al. (2004) in an experiment with potted gerbera grown in a mixture of perlite and sphagnum peatmoss (v/v=1/4) studied the use of nutrient solutions in the range of EC 0.2-1.7 mS cm^{-1}. Because of the plant quality, the authors distinguished EC 0.85 mS cm^{-1}, which allowed them to reduce the fertilizer use by 64% (in relation to the nutrient with EC 1.7 mS cm^{-1}). SIRIN (2011) investigated the usefulness of five nutrient solutions. However, he did not define the EC value in the cited paper. The solutions differed primarily in the concentration of nitrogen (from 50 to 210 mg N dm^{-3}) and potassium (from 66 to 277 mg K dm^{-3}). The author concluded that the most successful is cultivation of gerbera in perlite and peat mixture (V/V=1/1) is a solution with 150 mg N dm^{-3} and 234 mg K dm^{-3}. In the current horticultural practice, the EC of nutrient solutions for all cultivars of gerbera grown in soilless culture is within the range of 2.0-2.2 mS cm^{-1}.

The above data are contradictory, but our results may help to dispel doubts. For an evaluation of the appropriateness of a fertigation system it is most important to assess yields. The effects of different nutrient solution concentrations on both gerbera cultivars are shown in Table 3. The lowering of nutrient solution concentration by about 20% did not exert any effect on the number of flower heads, diameter of flower heads and length of the stem. Another element of the evaluation of fertigation is an assessment of the nutritional status of plants. The plants showed no symptoms of deficiency or excess of nutrients. The results of the chemical analyses of gerbera leaves in 2010 are shown in Figure 2 as an example. The concentration of macro- and microelements in leaves was compared with the guidelines published by PLANK (1988). The one hundred percent of the determined samples were found to be within the recommended value ranged for nitrogen, phosphorus, potassium, calcium, iron, manganese, copper and zinc. According to DE KREIJ at al. (1990), an optimum concentration of Cu varies from 3.8 to 12.7 mg kg^{-1}. DOLE and WILKINS (2005) recommended the range from 2 to 10 mg kg^{-1}. If we agree with these recommendations, the concentration in the nutrient solutions does not need correcting. However, because the Zn concentrations are also very close to the critical values, it would be safer to increase slightly the concentration of these two nutrients (Cu and Zn) in the solutions. The concentration of magnesium was above the recommendation of PLANK (1988), but not toxic. According to VALENZUELA DE OCAMPO (2001), the excessive level for magnesium is 1.2%.

Table 3

Effect of nutrient solution concentration on yield and quality of gerbera flowers

Cultivar	Nutrient solution (EC mS cm^{-1})	Number of flower heads produced by the plant	Diameter of flower heads (cm)	Length of the peduncle (cm)
2009				
Cafe	1.6	22.50	8.02	62.09
	2.0	20.75	7.89	60.82
	LSD	ns*	ns	ns
Kimsey	1.6	24.83	7.81	64.84
	2.0	27.83	7.96	64.41
	LSD	ns*	ns	ns
2010				
Cafe	1.6	15.99	8.12	62.90
	2.0	13.83	8.07	62.96
	LSD	ns	ns	ns
Kimsey	1.6	21.00	7.77	65.50
	2.0	23.01	7.97	64.32
	LSD	ns	ns	ns

* non-significant difference

As mentioned earlier, approximately 25% of the daily applied nutrient solution in open systems leaks out from a growing medium directly into the soil. This means that during a greenhouse cultivation of gerbera over an area of 1 ha, the total daily leakage was from 1.6 to 11.4 m^3 of nutrient solution. Interesting results were obtained by comparing the concentration of nutrients in the solutions supplied to the plants and in the drainage waters leaking out to the soil (mean values are shown in Tables 1 and 2). In both years, the concentrations of most ions in the leakage were higher than in the nutrient solutions applied for fertigation. Similarly, increased concentrations of most ions in solutions leaking out from substrates on which roses were grown in systems without nutrient recirculation were found by BLOEMEHARD and MOOLENBROEK (1995). The results of the chemical analyses indicate that the application of solutions with a lower EC did not cause any drastic changes in the plant root environment in comparison with standard treatments (EC 2.0). This result was achieved owing to a very low cation exchange capacity (close to zero), perfect air and water properties of perlite and regular renewal of the pool of nutrients owing to fertigation treatments repeated several times every day. According to ANHTURA (1988), horticultural

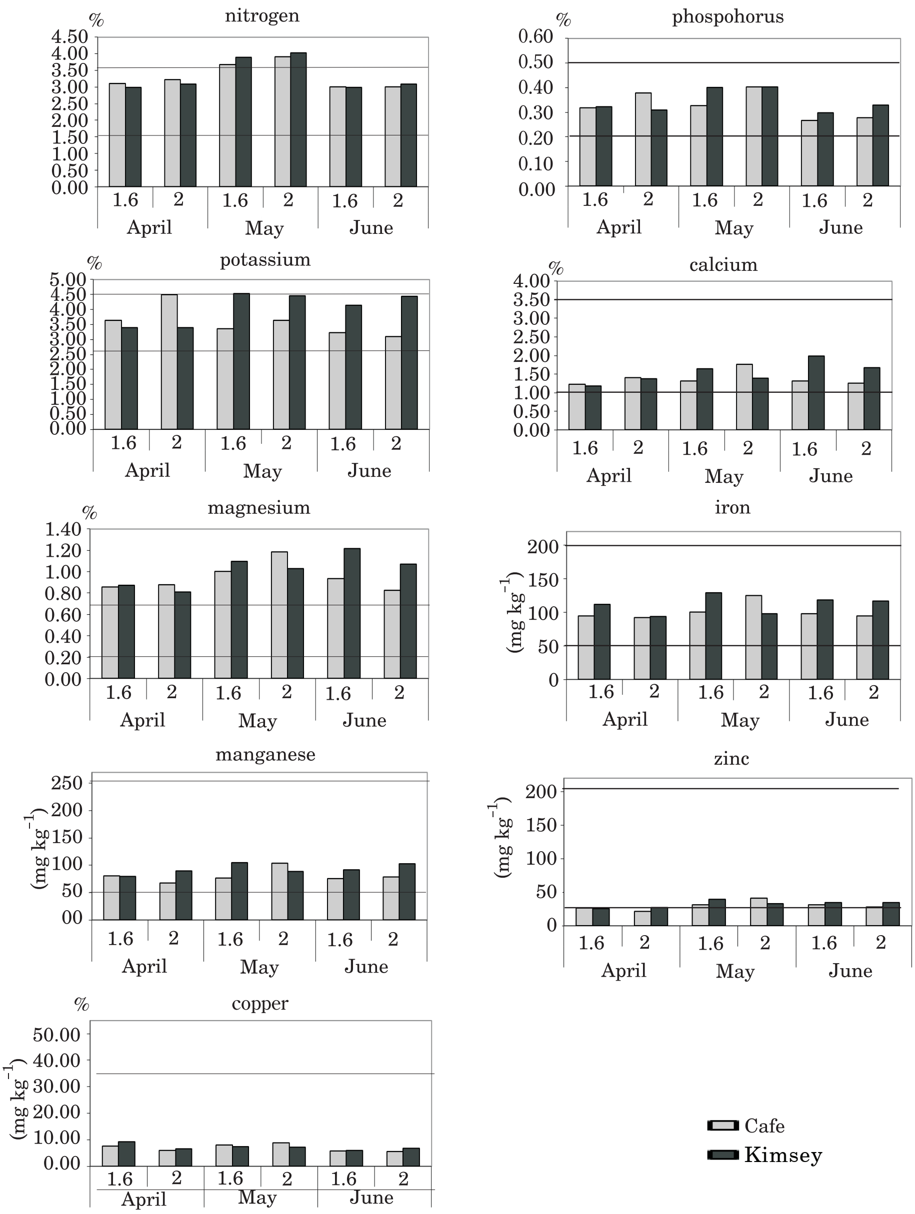

Fig. 2. The concentration of macro – (% d.m.) and microelements (mg kg^{-1}) in gerbera leaves depending on nutrient solution concentrations (mS cm^{-1})
Lines show the optimal range of nutrient concentration recommended by PLANK (1988)

perlite has the following physical properties: water capacity 21% and air capacity 75%. Perlite retains water around rather than inside granules. Thus, during a fertigation treatment water runs around perlite. Consequently, an increase in the ionic concentrations in drainage water leaking from the medium was negligible. According to BRES (2002), the increase in concentrations of nutrient solutions leaking from the root environment of gerbera grown in rockwool is higher. However, sometimes there is no increase in the nutrient concentration in the root environment. While growing anthurium in expanded clay pellets, a 9.5% decrease of EC was found (KLEIBER, KOMOSA 2006). On the another hand, in an experiment with tomato grown in perlite or expanded clay pellets, the concentration of drainage waters leaking from medium was higher than in solutions applied to the plants (JAROSZ et al. 2011). It seems that modifications in the composition of the rhizosphere and drainage water depend not only on the medium, but also on crop species and even on a cultivation system (DYŚKO, KOWALCZYK 2005).

The open fertigation system applied in horticultural practice is responsible for the chemical degradation of soil environment. During plant cultivation, the chemical composition of the leakages depends on the chemical composition of the nutrient supplied to plants, the plant age, the course of climatic conditions (especially of temperature), the time of the day and on the fertigation frequency (BRES 2010). For example, in Polish horticulture, the biggest pollution of the environment is caused by the fertigation of greenhouse tomato, whose cultivation area covers 2500 ha and the production cycle lasts about 10 months. Much lower pollution is caused by gerbera, which covers only about 90 ha. During commercial gerbera cultivation, the highest losses were shown by potassium (up to 413 kg K month ha^{-1}), nitrates (up to 231 kg NO_3-N month ha^{-1}), calcium (up to 220 kg Ca month ha^{-1}) and sulphur (up to 101 kg SO_4-S month ha^{-1}). The smallest losses were shown by microelements, from 0.01 kg of Mn and Cu to 3.46 kg of Fe month ha^{-1} (BRES 2009). In our experiments, $1m^3$ of leakage flowing from perlite contained 123-208 g N-NO_3, 40-69 g P, 173-358 g K, 111-140 g Ca, 38--52 g Na, 28-39 g Cl and 0.20-0.28 g B (calculations on the basis of chemical analyses of leakage). As mentioned earlier, in a greenhouse with a cultivated 1 ha area, the daily leakage was from 1.6 to 11.4 m^3 of nutrient solution. This input, especially of nitrogen (0.20-2.37 kg N daily ha^{-1}), is dangerous for the environment. Cultivation of gerbera in organic substrates was characterized by a lower run-off. The results of experiments by FERRANTE et al. (2000) showed that only 93 N, 6.8 P, 165 K and 107 Ca kg ha^{-1} per year are released into the environment. In order to restrain the excessive nitrate leaching from agricultural soils, the European Commission has issued the *Council Directive* (1991). The studies presented herein refer to this directive.

CONCLUSIONS

Concentrations of the nutrient solutions typically used for cultivation of miniature gerbera in perlite can be safely reduced to EC 1.6 ± 10% mS cm^{-1}. This will allow us to decrease the use of fertilizers by about 20%. It will also reduce the nutrient leakage to the soil and groundwater. However, a recirculation system is the most ecological solution and its application should be recommended. In the Netherlands, closed systems are compulsory. They largely improve the efficiency of water and nutrient use by cultivated plants and minimize pollution of the environment.

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