

## **LIMITING NUTRIENT EMISSION FROM A CUT ROSE CLOSED SYSTEM BY HIGH-FLUX IRRIGATION AND LOW NUTRIENT CONCENTRATIONS?**

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### **Abstract**

A two-year project was aimed at decreasing nutrient emission from closed nutrient systems by using high irrigation rates in order to allow lower EC levels in the presence of accumulated Na and Cl. Experimental variables were growing media, irrigation frequencies, EC and NaCl concentrations for cut rose 'Frisco'. Growing media used in the 3 liter containers (height 15 cm) were coir dust, and three perlite fractions. Irrigation frequencies were very high compared to normal horticultural practice, i.e. approximately 1, 1.9 and 3.8 l per plant/container per day throughout the experimental period.

No effects of the irrigation frequencies, or interaction of irrigation frequency with growing media or EC were found on production. Coir dust and fine perlite showed the highest production in the treatments, followed by the middle fraction perlite. Root FW, aboveground FW production and number of stems was lowest in the perlite 1-7 mm (coarse) treatment. It is suggested that the decreased growth in coarse perlite is the result of a higher resistance to root penetration.

From the root growth/production data, gas analysis in the rhizosphere, air-filled porosity and root ADH activity measurements it was concluded that oxygen deficiency did not occur in the growing media at the relatively high irrigation rates.

EC (0.9 and 1.9 mS/cm) and NaCl addition (0 and 10 mM) were used in order to simulate Na accumulating conditions in closed systems. A significant (negative) effect of NaCl on production was only apparent in the low EC treatment. Without NaCl in the nutrient solution, stem weight was highest at low EC. The apparent negative effect of NaCl at low nutrient-EC was particularly related to higher Cl concentrations in the leaves. The project confirmed that NaCl concentrations of 10 mM can be tolerated by cut rose provided nutritional elements are not below certain limiting concentrations.

Keywords: oxygen, run-off, Frisco, salinity, coir dust, perlite, NaCl, EC

### **1. Introduction**

To reduce emission from protected crop cultivation, closed systems have been successfully introduced in greenhouse horticulture. A limitation to the prolonged use of nutrient solution is the accumulation of Na - and to lesser extent- Cl in the recirculating solution. Particularly when water quality is low, the low uptake by horticultural crops may result in Na accumulation. The effects of Na and Cl accumulation can – when concentrations of all other nutrients remain constant – for most horticultural crops be attributed to osmotic/salinity effects. Ion-specific effects of Na and Cl are less common, but have been found in *Bouvardia* and *Aster ericoides* (Sonneveld et al 1999). For cut rose, no ion-specific effects have been found, and the crop proved to be relatively salt tolerant (Baas 2000, Raviv 2001).

In the Netherlands, run-off is only allowed when Na concentrations reach certain concentrations e.g. 4 or 8 mM. To reduce N and P in the run-off solution, their concentrations may be reduced. Since in hydroponics luxury consumption of nutrients occurs, relatively little is known about lower limits in nutrient concentrations. The aim of the project was to investigate whether lower concentrations than normally advised could be used in the presence of NaCl without adverse effects on production in order to decrease emission of N and P from closed systems. Since it was hypothesised that irrigation amount/frequency and growing media could be interacting factors in nutrient availability at these low concentrations, the experiments included these experimental factors.

## **2. Materials and methods**

### 2.1 Cultivation system

The experimental site consisted of 6 benches (length 12 meter, width 1.2 m) in a 150 m<sup>2</sup> greenhouse. On each bench two gutters were fixed on which containers (diameter 15-20 cm, height 15 cm, volume 3 l) filled with growing medium were placed. Nutrient solution was supplied with one dripper per container. The drained nutrient solution was collected in a 500-liter circulation tank. The containers were covered with plastic to avoid evaporation. Each experimental unit had a separate circulation tank and consisted of two rows of 6 m and 60 plants at the start of the experiment. Set-point temperature in the greenhouse was 18<sup>0</sup>C day/night during the experiment (5 plants per m). CO<sub>2</sub> was supplied at 1000 ppm in case no ventilation took place. Assimilation lighting was used from September until May if the outside radiation was less than 100 W/m<sup>2</sup>. No assimilation light was supplied from 8 p.m. until 4 a.m.

Through holes in the plastic, rose cuttings c.v. Frisco propagated in coir dust cylinders were planted in the growing media in week 40 1998.

The EC and pH of the nutrient solution in the circulation tanks was adjusted every week, and nutrient analysis was performed every two weeks. The amount of water and nutrients added to adjust to the target EC was recorded on a weekly basis. Target concentrations of major nutrients at 1.9 mS/cm were: (mM) NH<sub>4</sub> 0.1; K 5; Ca 5; Mg 3; NO<sub>3</sub> 12.5; SO<sub>4</sub> 3; P 0.9. At 0.9 mS/cm the ratio between all elements was kept the same as at 1.9 mS/cm. Target concentrations of minor element were always (μM): Fe 25; Mn 3; Zn 3.5; B 10; Cu 1; Mo 0.5. Growing media used were commercially available coir dust and perlite fractions. Irrigation frequencies were maintained primarily by a time-based control as follows: 1x/180 min, 1x/90 min, 1x/45 min with 35-40ml/min drippers. Duration of each irrigation was 3 minutes per irrigation throughout the experiment. Total irrigation per container/plant therefore was 960 ml, 1920 ml and 3840 ml per day.

During the project, the same plants were used in three different experiments.

The first experiment lasted from week 40 1998 until week 24 1999 in order to determine the extent oxygen deficiency in the roots may occur under high-flux irrigation conditions. Experimental variables were 4 growing media (coir dust, perlite fine (0-1 mm), mid (0.6-2.5 mm) and coarse (1-7.5 mm)) combined with 3 irrigation frequencies

(8, 16, 32x/day, corresponding with 960, 1920 and 3840 ml per plant per day). There were 4 replicates per treatment.

The second experiment was conducted from week 25 1999 until week 4 2000. Experimental variables were 3 irrigation frequencies \* 4 growing media \* 2 EC's of the nutrient solution (0.9 and 1.9 mS/cm). Irrigation frequencies and growing media were as in experiment 1. There were two replicates per treatment.

The third experiment lasted from week 5 2000 until week 32 2000. Experimental variables were 4 growing media \* 2 EC's of the nutrient solution (0.9 and 1.9 mS/cm). \* 2 NaCl concentrations (0 and 10 mM). The addition of NaCl resulted in an increase in EC of 1 mS/cm. There were 3 replicates per treatment. Irrigation frequency was 16x/day (1920 ml/plant.day).

Root weight was determined during experiment 1. Since the root samples were difficult to separate from the perlite particles at the last harvest, root dry weight of week 21 was determined by determining the organic matter content of the dried samples (at 70°C for 48 h) by heating at 450°C. Water content (%v/v) of the media was determined by weighing the pots at five dates during the experiment.

The activity of *in vitro* alcohol dehydrogenase activity (ADH) in root samples taken at different harvests in experiment 1 was determined as described by Baas et al. (1995, modified for cut rose 1997).

To obtain information on the aeration status of the growing media during experiment 3, gas samples were taken according to Wever et al (2001). Perforated PVC tubes (volume 3.8 ml) were brought horizontally into the growing medium at 5 cm from the bottom of the containers. The tubes were closed with a septum at the end, which allowed taking gas samples with a syringe. The samples (5 replicates per growing medium) were analysed for CO<sub>2</sub> and O<sub>2</sub> using gas-chromatography.

Leaf analysis was performed a number of times during the project. Only young fully expanded 5-leaflet leaves were harvested and analysed for Ca, K, Mg, P, total-N, NO<sub>3</sub>, Na and Cl.

Transpiration was determined on a weekly basis by determining the amount of nutrient solution needed to fill up the recirculation tanks to 500 l. Since the different growing media were combined per recirculation tank, no distinction could be made in transpiration between the growing media.

Production (number and weight of harvested stems) was determined up to three times per week by weighing and counting the harvested stems per plot.

For statistical analysis ANOVA was used; in only one analysis (Table 5) interaction effects were found. LSD at P=0.05 was calculated in case ANOVA indicated significant effects.

### **3. Results**

The results in Table 1 show that large differences in water content between the growing media existed; no significant differences between the frequencies were apparent however. The results fit - in comparison with laboratory results (not shown) - in the -3 to -32 cm pressure head range.

Root growth was clearly dependent on the growing medium. In coir dust and perlite fine root weights were considerably higher than in the perlite mid and coarse fractions (Table 2).

Root ADH activity as determined three times during experiment 1 showed large date-to-date differences. Although the trend was similar at all harvest dates only in week 12 a significant difference in ADH activity was found. The higher activities in fine perlite and coir dust correlated with the lower air filled porosities of these media at the same harvest date (Fig. 4).

The gas composition of samples taken 5 cm from the bottom of the containers showed that significant differences in concentration oxygen and carbon dioxide existed between the growing media (Table 3). The media with the lowest air content showed the highest carbon dioxide and lowest oxygen concentrations. However, the oxygen concentrations hardly differed from ambient conditions (greenhouse air).

No effects of the irrigation frequencies were found on production. There were also no significant irrigation \* growing medium interaction effects. However, the growing media differed in production parameters. Less stems per plant and FW per plant were produced in the coarse perlite compared to the perlite fine and coir dust treatments (Table 4). This difference had already developed in experiment 1, and persisted throughout experiments 2 (not shown) and 3 (Table 5)

With regards to the EC and NaCl treatments (experiment 3) there was a negative effect of NaCl addition on production (Table 5). However, this negative effect became only significant at the low EC treatment. In the absence of NaCl, the low EC treatment produced heavier stems than the EC 1.9 treatment.

Total transpiration over the experimental period was - although not significantly different - related to total FW production.

A clear effect of NaCl addition was visible in the Cl concentrations in the leaf (Table 6). Particularly in the EC 0.9 treatment Cl concentrations were high, which coincided with the lower production in the EC0.9 NaCl10 treatment.

Na concentrations were very low, and did not show significant changes, confirming the effective exclusion of Na by rose roots. With respect to the other major elements K, P and Mg were higher at higher EC. Total N was significantly higher in week 31 in the higher EC treatment. No significant differences in the Ca concentration were found.

#### **4. Discussion**

One of the prerequisites of the project was that the oxygen supply should not be limiting under high-flux irrigation conditions since water content would be close to container capacity which could induce oxygen deficiency. From the results (Table 1) compared to the physical characteristics (not shown), it was concluded that pressure head was between -3 cm and -32 cm in the 15 cm high containers. Under these conditions air-filled porosity was at least 25%. Although the induction of the enzyme ADH in the roots was somewhat higher in the growing media fine perlite and coir dust (Fig. 1) the differences between the growing media were small. Furthermore, gas composition in the bottom of the containers did hardly differ from ambient conditions (Table 3), and root growth (Table 2) and production (Table 4) were best in the 'wet' growing media. It is therefore concluded that the plants did not suffer from oxygen-deficient conditions under the given circumstances.

The results are in accordance with previous data on oxygen supply and stress in growing media. For instance, rose cuttings showed reduced root and shoot growth in rockwool blocks when air-filled porosity was below 25% around the roots (Baas et al. 1997). For chrysanthemum it was concluded that oxygen stress could be found at air-filled porosities already below 35%, although the effects very much depended on climatic

conditions (Baas and Warmenhoven 1995). In cucumber propagation in rockwool, no effects of high water contents (>80%) on shoot growth were found, and gas composition in the rhizosphere only started to differ at air-filled porosities below 25% (Baas 2001). Under these conditions, cucumber roots were more predominantly present in the upper layer of the rockwool, thereby probably avoiding oxygen deficient conditions. For cut rose, this avoidance could also be seen in the fine perlite treatment, since hardly any roots were present in the saturated bottom layer.

Finally, using respiration data of cucumber in combination with oxygen diffusion coefficients determined in fine perlite and rockwool, it was calculated that at an AFP of 30% or higher, no oxygen depletion in rockwool or perlite would occur (Baas et al 2001).

Differences in production were found between the growing media. Particularly the coarse perlite lagged behind in number of stems and total weight production per plant (Table 4). This reduction was already noticed in the first year of the project, and was related to less root growth in coarse perlite. Since there were no irrigation frequency \* growing media interactions, and no or hardly any effects on leaf nutrient concentrations, the growth could not be related to decreased nutrient or water availability in coarse perlite. It can be suggested that the penetration resistance in coarse perlite is higher than in the other growing media. The middle fraction perlite possibly with a presumed intermediate resistance showed intermediate root growth and production. It may be speculated that the decreased root growth exerts influence on the production and export of cytokinins, which subsequently affects shoot formation/bud break (Dieleman 1998) and hence may decrease production.

The project has shown that in the absence of NaCl, EC in the nutrient solution could be decreased to values of 0.9-1.0 mS/cm without adverse effects on production. Indeed, in the final experiment, stem weight was even highest in the EC 0.9 treatment. Although cut rose is not particularly salinity-sensitive (Sonneveld et al 1999, Raviv 2001) salinity tests usually were at EC levels starting from ca. 2 mS/cm. Cultivar Sonia grown in rockwool at low supply rates (de Kreij 1990) showed decreased production at EC 1.0 probably due to nutrient deficiency. Under our high-flux irrigation conditions, nutrient supply apparently was sufficient, although total N, P and K concentrations in the leaf were lower at EC 0.9 compared to EC 1.9 (Table 6). In contrast, Mg concentration was higher at low EC, possibly due to less K/Mg antagonism. The advantage of using EC 0.9 in open systems compared to e.g. EC 1.6 with respect to nutrient emission is obvious. In closed systems, the advantage of decreasing the EC of the nutrient solution is only relevant in case drainage solution is discarded in case of unacceptable high concentrations of e.g. Na and Cl. In the Netherlands these concentrations have been set at 4 mM for cut rose.

However, in the presence of NaCl, the positive effect of a low EC was counteracted. At EC 0.9 the addition of 10 mM NaCl negatively affected production, whereas this was not the case at EC 1.9 (table 6). The effect of NaCl on production was related to higher Cl concentrations in the leaf, but could – with the exception of slightly lower Mg concentrations – not be related to deficiencies. Na concentrations in the leaves were – as found before (Baas en van den Berg 2000) – very low. Since particularly the number of stems appeared to be reduced by the presence of NaCl (Table 5), it might be speculated that root formation/root death might have been affected by NaCl at low EC.

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Table 1. Water content (%v/v) in different treatments during experiment 1.

Growing medium	Frequency Irrigation	week 37	week 44	Week 50	week 12	week 21
Coir dust	1x/45 min	67	60	59	61	60
	1x/90 min			61	60	52
	1x/180 min			60	61	55
Perlite fine	1x/45 min	57	66	68	72	67
	1x/90 min			74	72	56
	1x/180 min			68	73	67
Perlite mid	1x/45 min	38	36	46	49	53
	1x/90 min			47	48	46
	1x/180 min			44	47	52
Perlite coarse	1x/45 min	27	26	35	37	40
	1x/90 min			32	34	35
	1x/180 min			37	38	42

Table 2. Root weight at harvests during experiment 1.

Growing medium	Week 44 (g FW)	week 50 (g FW)	Week 21 (g FW)	(g DW)
Coir dust	1.9	13.1	163	16.7
Perlite fine	1.5	8.9	140	10.2
Perlite mid	0.7	4.8	91	6.2
Perlite coarse	0.4	7.6	74	9.1
LSD	0.5	2.2	-	6.5

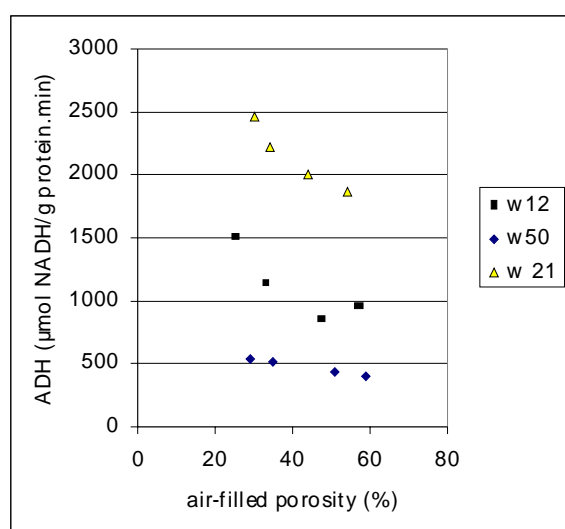


Fig. 1. Relation between air-filled porosity of the different growing medium and ADH activity of the roots for cut rose 'Frisco'.

Table 3. Oxygen and carbon dioxide concentrations in the media as determined in April 2000.

	O <sub>2</sub> (% v/v)	CO <sub>2</sub> (% v/v)
Coir dust	21.9	0.16
Perlite fine	21.8	0.25
Perlite mid	22.2	0.10
Perlite coarse	22.1	0.09
Control (greenhouse air)	22.1	0.04
LSD	0.1	0.08

Table 4. Production during the total experimental period week 40 1998 – week 32 2000)

Medium	no. stems/plant	FW/plant (g FW)	Stem weight (g FW)
Coir dust	95	2380	25.0
Perlite fine	96	2406	25.1
Perlite mid	90	2278	25.4
Perlite coarse	86	2167	25.3
LSD	6	154	-

Table 5. Production parameters and transpiration in experiment 3 week 5-32 2000

Treatment	No. stems/plant	Total FW/plant (g FW)	Average Stem weight (g FW)	Transpiration (liter/plant)
EC 0.9 NaCl 0	41.9	976	23.3	80
EC 0.9 NaCl 10	38.5	855	22.2	69
EC 1.9 NaCl 0	43.5	961	22.1	76
EC 1.9 NaCl 10	42.0	928	22.1	78
LSD	-	93	0.7	-
EC 0.9	40.2	917	22.8	74
EC 1.9	42.7	944	22.1	77
LSD	-	-	0.5	-
NaCl 0	42.7	969	22.7	78
NaCl 10	40.3	895	22.2	74
LSD	-	62	0.5	-
Coir dust	43.1	970	22.5	
Perlite fine	44.1	983	22.3	
Perlite mid	40.2	909	22.6	
Perlite coarse	38.5	855	22.2	
LSD	3.9	88	-	
NaCl*EC	-	-	*	-
EC*medium	-	-	-	-
NaCl*medium	-	-	-	-
NaCl*EC*medium	-	-	-	-

Table 6. Nutrient concentrations (mmol/kg DM) in young fully developed leaves sampled in weeks 12 and 31 2000

Treatment	Week 12 2000							NO <sub>3</sub>
	Na	Cl	K	Ca	Mg	P	Total N	
EC 0.9 NaCl 0	3	15	634	270	122	72	2183	
EC 0.9 NaCl 10	5	39	627	263	117	74	2221	
EC 1.9 NaCl 0	4	8	670	300	128	81	2251	
EC 1.9 NaCl 10	3	26	661	266	123	74	2197	
LSD	-	9	33	-	-	7	-	
Treatment	Week 31 2000							NO <sub>3</sub>
	Na	Cl	K	Ca	Mg	P	Total N	
EC 0.9 NaCl 0	1	29	663	229	151	66	1870	7
EC 0.9 NaCl 10	1	53	679	207	133	68	1925	9
EC 1.9 NaCl 0	1	11	728	224	143	73	2050	12
EC 1.9 NaCl 10	1	35	754	210	141	72	2040	10
LSD	-	8	32	-	7	3	97	-