GROWING NURSERY TREES ON ROCKWOOL

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INTRODUCTION

Some countries do not want to import nursery stock with soil on the roots for fear of soil pathogens. Therefore growing of trees and shrubs on artificial substrates is of interest (Verwer, 1974). In The Netherlands rockwool is used successfully as a substrate for cucumbers (Boertje *et al.*, 1979), and Larsen (1975) and Verwer (1974) mention the possibility of growing nursery stock on rockwool with daily trickling of a nutrient solution. Rockwool consists of very thin fibres of molten and sprayed rock material, mainly diabase, made cohesive with phenol resin and hydrophylic by means of additives (Jørgensen, 1975). It is a very porous material with a pore volume of 97%, and virtually inert, releasing only small amounts of Ca, Mg and Na (Virolainen, 1977) and especially Fe (Van Noordwijk, 1979). For transport of nursery trees, the light weight and coherent root system in rockwool block are additional advantages.

As a start, in the first experiment of 1976 different varieties of nursery trees were grown on rockwool blocks, trickled with two kinds of nutrient solution, in composition similar to those used in vegetable growing, to test the possibility of getting a marketable product on this substrate. The results were promising, and in 1977 and 1978 experiments were carried out with varying frequency of application and concentration of the nutrient solution to find the optimum supply.

Planting of plants, grown on rockwool blocks, can give difficulties because the blocks dry out by suction from the surrounding soil; at water tensions above pF 1.3 only little water remains (Van Noordwijk, 1979; Willumsen, 1972). For that reason the plants of the three experiments mentioned before were planted out, partly on a sandy soil, partly on a river clay soil with three ways of wintering, because not only soil type, nutrient status of the plant, but also wintering and winter damage might have influence on survival and regrowth after planting.

METHODS

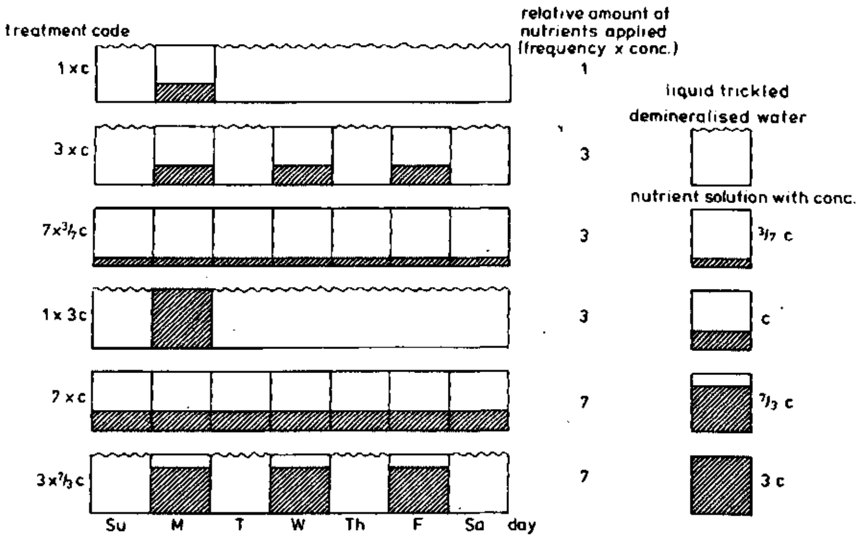
Experiment I (1976). On 10 June, cuttings of *Acer saccharinum* 'Pyramidale', A.s. 'Laciniatum', and *Salix acutifolia* 'Pendulifolia', and seedlings of *Juglans regia* were set in 6-liter rockwool blocks. The cuttings had been rooted and the seeds been sown beforehand in rockwool. The compositions of the two nutrient solutions used in the experiment are shown in Table 1. Solution I contains 0.8 g Nutriflora-t (2+11+40+5+ microelements) and 1.0 g $Ca(NO_3)_2$ per l demineralised water. Solution II is a combination of solutions A and B, described by Sonneveld and Voogt (1975) with, among others, the Danish products Fosmagnit and Mikronit. For each of the four varieties, four replicate plots with four plants each were used.

Table 1 Composition of the nutrient solutions I and II

Element	I	II	Element	I	II
	mmol per liter			µmol per liter	
N	12.3	13.1	Fe	30	36
P	1.26	1.00	Mn	20	20
K	7.18	7.00	B	32	29
Mg	1.04	2.00	Zn	3.8	7.5
Ca	4.25	4.50	Cu	0.27	0.32
S	3.22	3.25	Mo	0.60	0.52

Experiment II (1977). In rockwool rooted cuttings of *Salix erythro* 'Flexuosa' were set in 6-liter blocks on 18 May. The plants were grown as shrub. A nutrient solution of composition I (Table 1) was used and the frequency of applying and the concentration of the nutrient solution were varied (Figure 1). On days without nutrient addition demineralised water was given to the trees. The nutrient solution and demineralised water were trickled in this and also in the first and third experiment until some fluid appeared at the bottom. Frequency of trickling per day depended on the need of the plant for water. This means, however, that over a certain period the given nutrient supply for 1 x 3c is not exactly the same as for 3 x 1c because of differences in given liquid volume. However, over the entire season only

Fig. 1 The treatments in the second and third experiment (c= 0.8 g Nutriflora-t 2+11+40+5+ microelements and 1.0 g calcium nitrate per liter water). Treatment code = number of days in a week trickled with nutrient solution x concentration of solution trickled



small differences in nutrient supply occurred. The experiment consisted of 6 treatments in 4 replicates with 8 plants each.

Experiment III (1978). The design of the experiment was the same as in 1977. Rooted cuttings of *Acer saccharinum* 'Pyramidale' were planted in rockwool blocks on 1 June.

Planting of the plants grown on rockwool. In the autumn the plants of each treatment were split up into groups which were subjected to different methods of wintering: in the first experiment, the plants stood unprotected outside on the ground or in a greenhouse (temperature above 0 °C) and in the next two experiments there were three groups: autumn-planted in the soil, wintering outdoors on the ground or in a greenhouse (only *Salix* with temperature above 0 °C). The trees not planted in autumn were as yet planted in spring with extra watering for a few weeks. To test the influence of soil on survival, half of the plants were planted in a sandy soil and half in a river clay soil. *Liquid samples* were obtained by suction with an injection needle placed a few cm from the bottom of the rockwool block, biweekly in experiment

I, once a week in the others. In the liquid the electric conductivity (EC) and pH were measured. The samples of a few dates were more extensively analysed.
Leaf samples in autumn in trial II and III were analysed for N, P, K and dry matter.

RESULTS

Growth on rockwool blocks

Testing two kinds of nutrient solution (Experiment I). Growing of nursery stock on rockwool blocks outdoors with daily trickling of nutrient solution appeared to be very successful. The differences between the effect of the two nutrient solutions were not statistically significant and for most kinds of trees tested very small. Figure 2 shows the growth pattern of stem length and thickness of the different plants. For *Juglans regia* solution II gives longer stems than solution I, but sprouting varies from plant to plant and this can give a great variation without a real difference between the averages.

Influence of frequency of application and concentration of the solution (Experiments II and III). Because in 1976 growing on rockwool blocks was found possible, in the following experiments the optimum nutrient supply was emphasized. Because the two nutrient solutions were equally effective, the simplest one to prepare, based on Nutriflora-t and calciumnitrate, was used. In the experiments many plant growth characteristics were recorded; there was a high degree of positive linear correlation between most of them. A part of them, connected with vigour of growth, was negatively correlated with the dry-matter percentage of the leaf, indicating a reduction in dry-matter content when plants grew more luxuriously. Figure 3, which gives stem thickness, an important characteristic for market value, shows that daily trickling of standard solution c, containing 0.8 g Nutriflora-t and 1.0 g calciumnitrate per liter, gave the best results. Less frequent trickling of nutrient solution decreased growth, not wholly compensated for by the favourable effect of increasing the concentration. Growth with nutrient solution supplied one day a week, even with a tripled concentration, remained clearly behind. Regarding the interaction between frequency of trickling 3 or 7 times a week, respectively, and the added amount of nutrient, it was found that an increased fertilizer addition was more favourable for *Salix* in the case of a low frequency in comparison with a high frequency, but for *Acer* growth was furthered more by an increased amount if each day was trickled rather than 3 times a week (Table 2).

<u>Fig 2</u> **<u>Influence of two kinds of nutrient solution on growth of nursery stock on rockwool</u>**

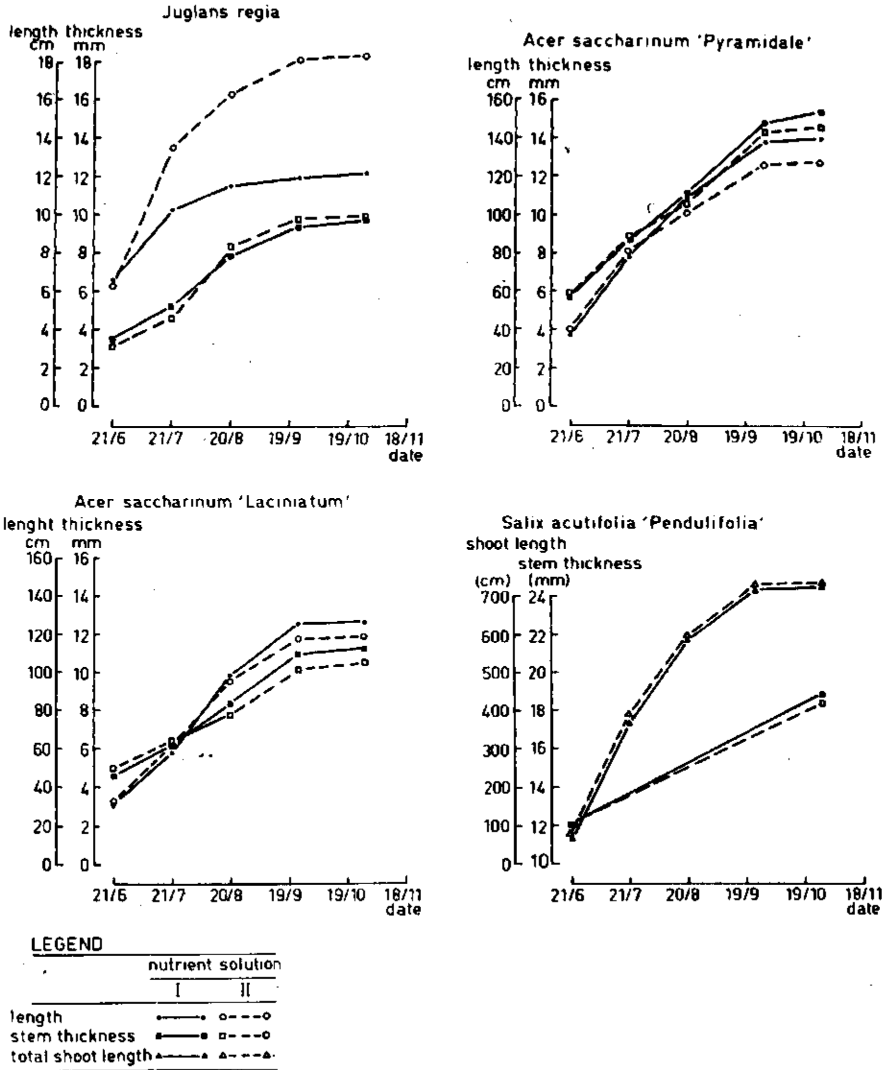


Fig 3 Influence of frequency of trickling and concentration of nutrient solution on growth of *Salix* and *Acer*

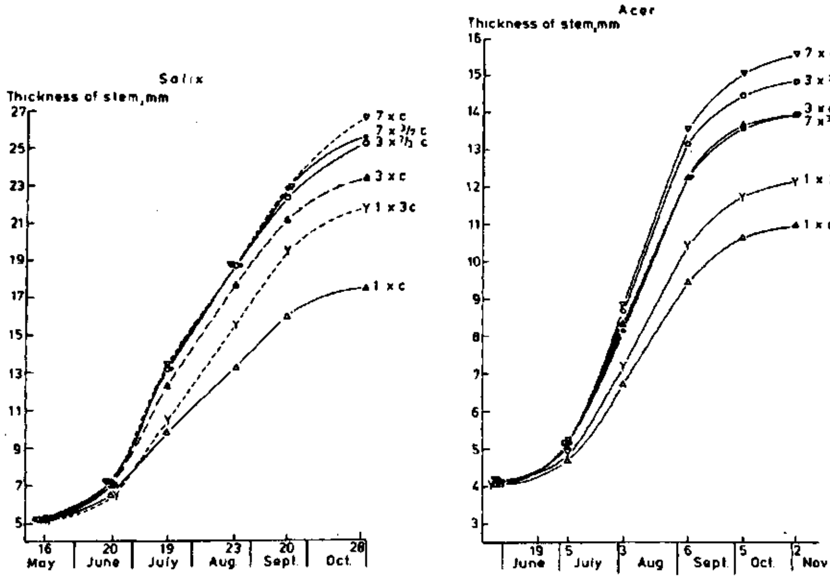


Table 2 Interaction between frequency of trickling and amount of nutrient. Treatment code: number of days a week trickled-added amount of nutrient (=times per week x concentration). Measurements in autumn.

Plant	Plant feature	Treatment			
		3-3xc	3-3x7/3c	7-7x3/7c	7-7xc
Salix	stem thickness in mm	21.2	22.4	22.9	23.0
	shoot length in m	4.76	6.16	5.88	5.79
Acer	stem thickness in mm	14.0	14.9	14.0	15.6
	stem length in m	1.18	1.28	1.08	1.43

Nutrient composition of the rockwool liquid. The pH and EC values of the liquid sampled weekly or biweekly from the blocks fluctuated widely between and within years (Table 3).

Table 3 Range of liquid composition in rockwool blocks for treatment 7 x c and recommended values for cucumber (Boertje et al., 1979)

Element	Recommended values	Range of observed values		
		Acer (1976)	*Salix* (1977)	*Acer* (1978)
pH	5.5-6.5	4.2-6.8	5.4- 8.1	4.6-6.4
EC, mS/cm	2.0-2.5	1.3-2.0	2.0- 4.0	1.6-2.1
N, mmol/l	8 -12	11 -13	8 -28	5 -13
P, "	1 -1.5	1.1-1.3	0.3- 1.9	0.7-1.4
K, "	4 -6	7 -14	7 -14	6 -8
Mg, "	1.3-1.8	0.9-1.7	1.1->4.5	1.2-1.8

As no visual damage in the plants was observed, no change in nutrient solution composition was made except in 1977 for *Salix*, when the pH increased to above 8.0. Then the risk of too low an Fe availability was no longer accepted, H_3PO_4 was added. Table 3 shows that good growth is possible within a wider range than given by Boertje et al. (1979) for cucumber on rockwool. A study was made to find the causes of the fluctuations of pH and EC within the season. A part may be ascribed to the given amount of solution. After warm days with a higher supply the pH tended to be lower and the EC higher.

Growth after planting in the soil

Good growth on rockwool blocks does not necessarily mean good development after planting. Therefore in planting experiments different factors, soil type and wintering method, were investigated in combination with the differences obtained in nutrient status of the plant. For river clay, only general impressions of rooting and growth of the plants are present. *Salix acutifolia* 'Pendulifolia' of the first trial suffered from top death, but the other trees grew well. Probably due to lack of water all *Salix erythro* 'Flexuosa' of the second trial died on the river clay soil. In the first experiment, growth on the sandy soil of plants wintered in the greenhouse was a little better than of those wintered outside on the ground, except for *Juglans*. In the second trial the *Salix* shrubs were attacked by the fungus *Glomerella cingulata*, the heaviest attack occurring on the plants that wintered outdoors on the ground. There was also an after-effect of nutrient supply given in the preceding year. The affection was less in the plants trickled with the lowest frequency of nutrient solution (Table 4).

Table 4 *Salix* planted on sand: shoots diseased by *Glomerella cingulata* in August (percentage of fresh weight) and fresh weight in autumn

Plant	Wintering	Treatment					
characteristic	method	7x3/7c	1xc	3xc	7xc	3x7/3c	1x3c
diseased shoots, %	autumn planted	4.5	4.4	5.1	4.5	5.4	3.2
	outside	9.0	10.3	12.7	11.2	10.2	7.4
	greenhouse	4.6	2.7	3.5	4.0	3.2	3.6
fresh weight, kg/plant	autumn planted	1.55	0.77	1.19	1.29	1.27	1.14
	outside	1.35	0.60	0.87	1.01	1.31	0.90
	greenhouse	1.10	0.71	1.28	1.33	1.25	1.30

The greatest fresh weight was obtained with autumn planting of shrubs which received treatment 7 x 3/7 c in the preceding year. Many of the *Acer* which had wintered in a greenhouse died in the second year on sand and clay. Striking is that, on sand, the trees planted in autumn grew best, but on clay the plants wintered outside on the ground produced the best growth. The first may be expected as there is a longer opportunity for root development before leaf emergence, and the latter may be indicative of aeration problems on clay in winter. At the end of the planting experiment, the best plants on sand were those which received, on rockwool, treatment 7 xc and 3 x 7/3 c and on clay those with 7 x c (Table 5).

Table 5 Stem length of *Acer* on sand and clay in the autumn of the second growing season (m/plant)

Soil	Wintering method	Treatment					
		7x3/7c	1xc	3xc	7xc	3x7/3c	1x3c
Sand	autumn planted	1.95	1.99	2.09	2.28	2.31	2.09
	outside	1.76	1.99	2.07	2.16	2.28	1.93
	greenhouse	1.61	1.73	--	0.79	--	1.08
Clay	autumn planted	1.25	0.80	1.14	1.48	1.28	1.33
	outside	1.90	1.55	1.73	2.13	1.79	1.70
	greenhouse	1.37	1.49	1.49	1.75	1.30	1.15

DISCUSSION

Good growth of nursery stock on rockwool was obtained. The best treatment was daily trickling of a nutrient solution (7 x c), but sufficiently good performance was seen in a few other combinations of frequency of application and concentration of nutrient solution. With too low a frequency of application in a week, however, growth fell behind. After a couple of days of trickling of just water, little nutrient in the blocks will remain. As consequence of the uniform pore size, the dispersion is small and the nutrients present are practically completely displaced (Van Noordwijk, 1978). Moreover, adsorption is of little importance.

A drawback of this growing system is the high amount of fertilizer added. Daily added volumes of nutrient solution ranged for treatment 7xc in the three experiments from 0 to 2.2 l. Total supply till the end of October for treatment 7xc varied in the three experiments as follows: N 450-870 and K_2O 840-1710 kg/ha/year (based on 29.000 trees per ha). It is desirable to decrease these amounts, also from the viewpoint of environment pollution. To what extent frequency and concentration may be lowered can be estimated from the course of the nutrient content of the rockwool liquid during the season. The poorer growth of treatment 1 x c was accompanied by a gradual decrease in nutrient content in the course of the season, indicating too low a concentration. For *Acer* in 1978 (Table 3), treatment 7 x c showed a more or less stable nutrient content on a level considered good for cucumber. Water uptake and nutrient supply are in balance. N and especially K and Mg reached high values in *Salix* in 1977, probably due to a higher water demand of this plant, with accumulation of salts in the rockwool blocks as consequence. This suggests that during summer when transpiration is high, a more diluted solution may be used (Wiersum, 1973). Another possibility of saving on fertilizer is to select a ratio between nutrients that is better adapted to plant growth. Comparison of nutrient ratios in the fertilizer, the leaf and the rockwool liquid will show if the elements are supplied in the right mutual proportion. In view of the lower K leaf content of *Acer* and the higher K liquid level, too high a K level of the fertilizer may be assumed (Table 6). The same tendency was apparent for phosphate. In *Salix*, insufficient P and K was added compared with N. In July, the P content of the rockwool liquid was very low and distinctly below the recommended level. In the first experimental year at the end of the season, *Acer saccharinum* 'Pyramidale' and *Salix acutifolia* 'Pendulifolia' showed leaf symptoms like those due to Mg-deficiency on solution I, but not on solution II, the Mg-concentration of which was almost twice as high (Table 1).

Table 6 Ratio between N, P and K (mmol) in the fertilizer and for treatment 7 x c in leaf and rockwool liquid in *Salix* and *Acer*

Nutrient content of	Ratio between		
	N	P	K
Nutriflora-t+calcium nitrate	1.00	0.10	0.58
Leaf of *Salix*	1.00	0.07	0.40
Acer	1.00	0.08	0.33
Liquid for *Salix*	1.00	0.07	0.31
Acer	1.00	0.16	1.25

Finally, discontinuation of trickling nutrient solution earlier in autumn should also be mentioned as a way of saving on fertilizer.

Wintering and planting have given some unsatisfactory results without a clear cause. Unprotected wintering of plants in rockwool blocks outside on the ground is possible, but unfavourable weather conditions appeared to have stimulated fungus attack in *Salix*. On the other hand, greenhouse wintering also has its problems; drying out and aphid attack must be avoided, the latter probably having caused dying of *Acer*. The advantage of autumn planting can only be realised if the soil is in a good condition, as the results on clay showed. Replanting of trees on sandy soil did not give any problem. However, especially on clay, rockwool blocks, having a low water-holding capacity, may dry out due to suction of the soil. The roots of *Salix* in the second trial, strongly coiled up at the bottom of the blocks, did not elongate sufficiently on clay. Maybe, before planting the root mat should be loosened. In any case, extra watering during a longer part of the season is necessary on clay.

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SUMMARY

To comply with import regulations set by some countries, growing nursery trees on artificial substrates without soil pathogens is of interest. In the first year of experiments, good growth of four nursery tree species on rockwool blocks was obtained with two kinds of trickled nutrient solution. In the next two years, frequency of application and concentration of the nutrient solution were varied. Salix *and* Acer *grew most vigorously with daily trickling of a nutrie solution, containing 0.8 g Nutriflora-t 2+11+40+5 and 1.0 g calcium nitrate per l. Trickling nutrient solution once a week gave distinctly poorer growth, even when the concentration of the nutrient solution was increased. Replanting of trees, grown on rockwool blocks, withou prolonged watering can give problems on clay.*