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INTRODUCTION

In the Netherlands, tomatoes and cucumbers have been grown in rockwool on a commercial scale for several years now. The technique of growing in rockwool originated in Denmark and Sweden. A more or less individual system was developed in the Netherlands which is described in this publication.
Besides tomatoes and cucumbers, other crops are also grown in rockwool in the Netherlands. However, experience with the latter is still limited and for this reason only the culture of the two crops mentioned is described in this publication.

PROPERTIES OF ROCKWOOL

Rockwool is made of diabase, coke and limestone. These materials are molten at a temperature of 1,600°C and spun into fibres. The fibres are woven into slabs, stabilised with phenolic resin and provided with a wetting agent.
The chemical composition of the most widely used rockwool (trade mark Grodan) as provided by the manufacturers, is shown in Table 1.

Table 1 The chemical composition of rockwool - trade mark Grodan - as given by the manufacturer

	%		%
SiO_2	47	Na_2O	2
CaO	16	K_2O	1
Al_2O_3	14	MnO	1
MgO	10	TiO_2	1
FeO	8		

The elements mentioned in the Table are present in the rockwool in such a form that they are practically unavailable to the plants. It is possible that plants may benefit to a limited extent from the calcium, magnesium, iron and manganese present in the rockwool. This may be relatively important for trace elements such as iron and manganese.
Rockwool has a slightly alkaline reaction which is the reason why nu-

trient solutions with a somewhat lower pH, show an initial increase in their pH value when they are introduced into the rockwool slabs. However, the rockwool is usually neutralised after a short time and it may then be regarded as an inert material with regard to the pH. These experiences confirm the results of work by Van Noordwijk (1979). Depending on the basic materials and the manufacturing process used, the chemical properties of rockwool may deviate from those mentioned above.

With regard to the physical properties, it may be said that rockwool has a low volume weight, a large pore volume and a great water retention capacity at low matric suction. Table 2 shows some results of physical measurements carried out on a rockwool sample manufactured by Rockwool Lapinus, the Netherlands, during the season 1979 - 1980. The moisture contents found at various pF values agree reasonably well with the values recorded by Willumsen (1972) and by Van Noordwijk (1979). However, experience in recent years has shown that small deviations in the manufacturing process may often produce large differences in the physical characteristics of rockwool.

Table 2 Physical characteristics of rockwool

	value	units
Pore volume	97.8	%
Bulk density	60.6	$g.dm^{-3}$
Water at pF 0.57	90.8	% (by volume)
Water at pF 1.05	38.6	% (by volume)
Water at pF 1.52	2.2	% (by volume)

MATERIALS AND SYSTEMS

The volume of rockwool used for tomatoes and cucumbers in the Netherlands at the moment is usually 14 l rockwool per m2 glasshouse area. For tomatoes, this quantity is divided over four rows of 15 cm wide slabs per glasshouse bay (3.20 m wide). Cucumbers are planted on two rows of 30 cm wide rockwool slabs per bay. In both cases the thickness of the slabs is 7½ cm.

Trials carried out at the experimental stations at Vleuten and Sappemeer during 1978 and 1979, have shown that it may be possible to reduce the volume of rockwool. The results of the experiments are summarised in Table 3. The differences between the volumes were not significant. The results confirm experiments carried out in Sweden which showed that various - rather large - volumes of rockwool did not produce significant differences in yields (Haupt Jörgensen and Jonssen, 1978 a and b, Haupt Jörgensen and Ottoson, 1978). Experiments carried out by Wiersum (1978) also indicated that it must be possible to grow in small root volumes. The volumes for tomatoes and cucumbers could

reduced to 0.5 and 1 l per plant respectively without affecting the requirements of the plants. The practical possibilities of reducing the root volume will be studied in further experiments in the Netherlands. Factors such as the uniformity of the substrate and the accuracy with which the water is distributed by the irrigation system will undoubtedly require attention in the experiments.

Table 3 Yields of cucumbers and tomatoes, expressed as $kg.m^{-2}$, in experiments in which different root volumes, different makes of rockwool and new rockwool slabs were compared with slabs used for one season

Cucumbers

Trade mark	rockwool dimensions in cm				
	30 x 7.5 used	30 x 7.5 new	20 x 7.5 new	15 x 7.5 new	15 x 10 new
		Vleuten 1978, autumn crop			
Grodan	-	15.9	-	15.4	15.2
		Vleuten 1979, spring crop			
Grodan	31.4	31.2	29.8	28.6	-
Basalan	-	30.3	-	29.8	
		Vleuten 1979, autumn crop			
Grodan	9.9	9.4	9.9	9.5	-
Basalan	-	10.4	-	9.3	
		Sappemeer 1978, spring crop			
Grodan	-	36.0	-	35.0	34.6
		Sappemeer 1979, spring crop			
Grodan	35.2	32.4	33.6	33.1	-
Basalan	-	34.1	-	32.6	-

Tomatoes

Trade mark	rockwool dimensions in cm	
	15 x 5	15 x 7.5
	Vleuten 1979, spring crop	
Grodan	21.3	21.6

In the trials carried out at the experimental stations mentioned, comparisons were also made between new and used rockwool slabs. The data in Table 3 show that the yields obtained with used rockwool slabs were as good as those obtained with new slabs. Practical experience in commercial nurseries also shows that rockwool slabs may

be used for several consecutive years. However, in that case steam sterilisation or chemical disinfection may be necessary at the end of each growing season.
It is most important that the rockwool slabs are laid down evenly and the glasshouse floor should be levelled beforehand. Small variations in level may cause large differences in the moisture content. The rockwool slabs are generally wrapped in plastic film and laid down on polystyrene slabs. As a rule, the units should not exceed 3 to 4 m in length in order to avoid water displacement over longer distances if the glasshouse floor is not perfectly level.
For an early winter crop of cucumbers it is necessary to install heating under the slabs and it is also advisable to do so for tomatoes. The heating system consists of alkathene tubes which are laid in grooves in the polystyrene slabs under the rockwool slabs.

WATER QUALITY AND IRRIGATION

Water of good quality is essential for crops in rockwool as the root volume is small and the buffering capacity of rockwool fibres is low. Cropping in a small root volume may result in a rapid salt accumulation and because of the low buffering capacity, any toxic compounds present in the irrigation water may cause damage more readily to a crop in rockwool than in glasshouse soil. In order to prevent excessive salt accumulation, the sodium and chloride contents for instance should preferably be below 1.5 $mmol.l^{-1}$ and the electrical conductivity (EC) below 0.5 $mS.cm^{-1}$ (Sonneveld, 1980). It is possible to grow in rockwool at higher values than those mentioned provided frequent flooding is practised. This results in a substantial loss of fertilisers through leaching.
Irrigation water containing bicarbonate should be neutralised with acid in order to avoid an excessive increase in the pH of the nutrient solution in the rockwool slabs. Nutrient ions, such as calcium, magnesium, sulphate, boron and manganese, which are often already present in water, should be taken into account in the composition of the nutrient solution.
The water is applied with a trickle irrigation system. Unfortunately, this may cause problems through blocking of the nozzles. It is therefore most important to install an effective filter and to use a trickle irrigation system which is less prone to blocking. All materials which come into contact with water and nutrient solutions should be corrosion resistant. Metals can corrode very quickly resulting in undesirably high levels of metal ions in the nutrient solution. Plastic materials are generally good to use.
The quantity of water which should be applied depends on the size of the plants, the level of radiation and the heating. Attempts are being made to automate irrigation in various ways. Factors involved in the automation are radiation intensity or moisture content of the rockwool slabs. The latter factor is measured by moisture sensors or by continuous weighing of a number of rockwool slabs in which plants

are being grown (Anonymus, 1978 and Van Schie, 1979).

NUTRIENT SOLUTIONS

Nutrient solutions for various crops in rockwool have been developed at the Research Station at Naaldwijk. The composition of the nutrient solutions for tomatoes and cucumbers are shown in Table 4. Readily available fertiliser salts and acids are used for the solutions and iron is applied in the form of Fe-DTPA.

Table 4 Composition of the nutrient solutions used for cucumbers and tomatoes grown in rockwool

Major elements	Contents in $mmol.l^{-1}$	
	Cucumbers	Tomatoes
K^+	6	7.5
Ca^{++}	3.5	3.75
Mg^{++}	0.75	1.0
NH_4^+	0.5	0.5
NO_3^-	11.5	10.5
$H_2PO_4^-$	1.5	1.5
SO_4^{--}	1.0	2.75
Trace elements	**Contents in $\mu mol.l^{-1}$**	
Fe	10	10
Mn	10	10
Zn	4	4
B	20	20
Cu	0.5	0.5
Mo	0.5	0.5

The fertilisers are dissolved in two separate concentrated stock solutions which are diluted in the irrigation water. One stock solution - component A - consists of the fertilisers which do not contain sulphates or phosphates, while the other stock solution - component B - consists of the calcium-free salts. This is done to prevent precipitation of the salts into calcium phosphate and calcium sulphate. As already mentioned, the quantities of nutrient ions and bicarbonate present in the irrigation water should be taken into account in the preparation of the nutrient solutions. The Research Station at Naaldwijk has published a large number of formulae for stock solutions which makes it possible for growers to readily choose a solution to suit the irrigation water available on the nurseries (Sonneveld and Voogt, 1978 a and b). For example, Figure 1 shows a formula which is widely used for cucumbers irrigated with rain water. The zinc sulphate may often be omitted from the nutrient solution as the rain

water in the Netherlands generally contains sufficient zinc already.

Figure 1 An example of the fertilisers used in the preparation of the nutrient stock solutions for growing cucumbers in rockwool irrigated with rain water or desalinated water

Cucumbers in rockwool — Formula A o.o.o

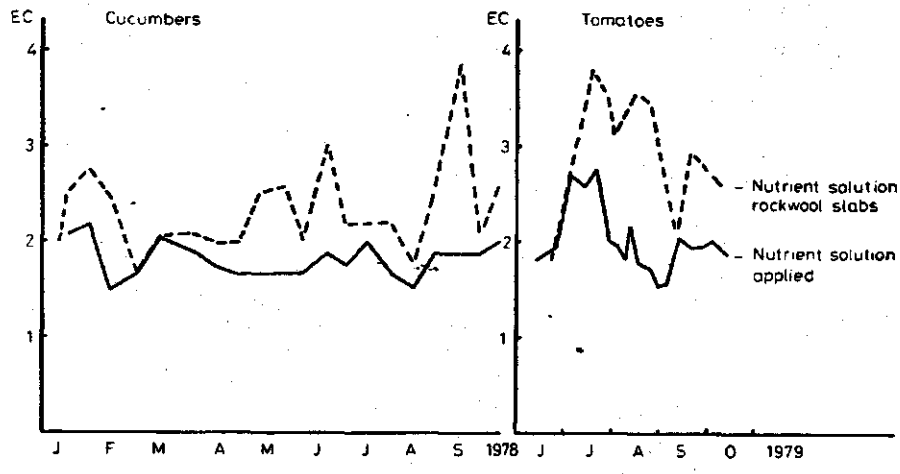
		acid o mmol	corrected o mmol Ca^{++} o mmol Mg^{++}
Stock solution A	nitric acid (37%)	-	kg
	calcium nitrate (15.5% N)	63.7	kg
	potassium nitrate	10.0	kg
	ammonium nitrate	4.0	kg
	iron chelate Fe-DTPA (9%)	560	g
Stock solution B	nitric acid (37%)	-	kg
	potassium nitrate	30.4	kg
	monopotassium phosphate	20.4	kg
	phosphoric acid (37%)	-	kg
	potassium sulphate	4.4	kg
	magnesium sulphate	18.5	kg
	manganese sulphate	160	g
	zinc sulphate	110	g
	borax	180	g
	copper sulphate	12	g
	sodium molybdate	12	g

100 times concentrated nutrient solution.
Quantities per m^3.

The stock solutions are added to the irrigation water in such a concentration that the EC of the nutrient solution in the rockwool slabs

is maintained at between 2.0 and 2.5 $mS.cm^{-1}$ at 25°C for cucumbers and at 2.5 to 3.0 $mS.cm^{-1}$ for tomatoes. As a rule, these values may be achieved by adding so much of the concentrated nutrients to the irrigation water that the EC of the nutrient solution is between 1.5 and 2.0 for cucumbers and between 1.7 and 2.2 for tomatoes. As young, vigorously growing crops have a high nutrient uptake, it may be necessary to maintain higher nutrient levels in the irrigation water. Figure 2 shows the pattern of the EC of the nutrient solution applied and of the nutrient solution in the rockwool slabs in a cucumber and a tomato crop.

Figure 2 The pattern of the EC of the nutrient solution applied and of the nutrient solution resulting in the rockwool slabs. The results for cucumbers were obtained on a glasshouse nursery at Pijnacker and the results for tomatoes were obtained in an experiment at the Research Station at Naaldwijk



For tomato crops, higher EC values for the nutrient solution in the rockwool slabs may be maintained from time to time. This is the case for instance when the plants are growing under poor light conditions or during periods when higher EC values are required to obtain more uniform ripening of the fruit.

The pH of the nutrient solution in the rockwool slabs should preferably be maintained between 5.0 and 6.0. This may be achieved by ensuring that the pH of the nutrient solution applied is of the same, or a slightly lower value. The pH of the nutrient solution in the slabs

may be adjusted by the acid application or by omitting ammonium nitrate. If in case of no acid or ammonium application the pH still remains too low, a little potassium bicarbonate may be added.
The EC and the pH of the nutrient solution in the rockwool slabs are checked by the grower once or twice a week with the aid of portable instruments. All the important elements should be determined in a laboratory once or twice a month. If necessary, the stock solution is adjusted according tot the analytical results.

GROWING CONDITIONS

The plant material for rockwool growing should be raised preferably in rockwool cubes. The nutrient solutions shown in Table 4 may be used for wetting the cubes and for watering during the plant propagation period. A nutrient solution with a concentration equivalent to EC 2.0 is generally used initially. For cucumbers the EC value of the nutrient solution in the cubes may be increased gradually to between 2.5 and 3.0 and for tomatoes to between 3.0 and 4.0. The pH level should be maintained preferably at between 5.0 and 6.5 It is most important that the temperature in the cubes is maintained at a sufficiently high level because at low temperatures Phytium may become a problem. The minimum temperature for cucumbers is 22°C and for tomatoes 20°C.
The rockwool slabs should be saturated completely with nutrient solution before the young plants are set out on the slabs. If the light conditions are poor at the time of planting, it is normal practice to restrict root growth for several weeks by placing the young tomato plants on a strip of polythene film laid on top of the rockwool slabs. If tomato plants are allowed to root directly into the slabs under poor light conditions, they would take up water too readily which would result in lush and lanky growth. In order to avoid this, the EC of the nutrient solution in the cubes is also often increased to values between 5 and 10. Under good light conditions, the tomato plants are set out directly on the saturated rockwool slabs. Cucumbers are always planted out directly on the slabs. As soon as the plants have rooted through into the rockwool slabs, usually one or two weeks after setting out, slits are cut in the polythene wrapping of the rockwool slabs in order to allow surplus water to drain away. The ambient temperature for a cucumber crop on rockwool is maintained at the same levels as for a crop in soil. Tomatoes seem to be better grown at temperatures which are 1 or 2°C lower than the temperatures for a crop in soil. The temperature in the rockwool slabs should be maintained preferably at 20°C for tomatoes and a few degrees higher as the minimum temperature for cucumbers.

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SUMMARY

The production of tomatoes and cucumbers in rockwool has steadily increased in the Netherlands in recent years. The rockwool growing techniques developed in Scandinavia were used initially, but a

slightly different growing method was adopted eventually. This method is discussed in this publication.
The chemical and physical properties of rockwool are described as well as the quantity of rockwool required and the methods of lay-out and irrigation. The requirements with regards to water quality and the basic compositon of the nutrient solutions for the tomatoe and cucumber crops are also examined.
Brief directions are given for the rising of the plant material, for the control of the environmental conditions and for the control of the nutrient level in the rockwool slabs by means of the pH and the EC values measured once or twice a week by the grower himself. It is recommended to check the composition of the nutrient solution in the rockwool slabs in a laboratory once ore twice a month.