PROEFSTATION VOOR TUINBOUW ONDER GLAS TE NAALDWIJK

The influence of different glass wool types and two irrigation frequencies on production and root distribution of cucumber.

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Summary

In two cucumber crops three glass wool substrates of 7.5 cm height were combined with two irrigation frequencies. Substrates A and B had small pores, substrate C had big pores. To modify the root distribution a glass wool film was placed in substrate B at 2.5 cm from the bottom of the substrate. A gift of 200 ml was given after a calculated evaporation of 50 and 150 ml at the high and low irrigation frequency respectively.

In the first crop no differences in water content were observed between the treatments. In the second crop the low irrigation was not sufficient to compensate for the evaporation of the plants, the substrates dried out. In this crop the water content in substrate C was for both irrigation frequencies 15% lower than the other substrates.

In both crops the substrates with small pores gave higher yields than the substrate with big pores, even at the high irrigation frequency. In the second crop the number of fruits was higher for substrate B with glass wool film but the weight did not increase. The low irrigation frequency gave in the first crop the best production. In the second crop the low irrigation gave a reduced yield caused by a lack of water in some periods.

After the second crop the root distribution was determined. In glass wool A a regular root distribution was found. Substrate B had a regular root distribution with an accumulation of roots around the glass wool film. In glass wool C many roots were at the bottom of the slab, higher in the slab the root density decreased.

Samenvatting

Glaswolsubstraat met kleine poriëen, grote poriëen en kleine poriëen met glasvlies is onderzocht. Met het glasvlies is getracht de luchtvoorziening van de wortels te verbeteren door de wortelverdeling te beïnvloeden. Twee gietfrequenties zijn gekozen waarbij per druppelbeurt 200 ml werd gegeven. De bijbehorende drainfracties waren 25 en 75 %. De motivatie voor de druppelfrequenties was enerzijds de mogelijke invloed op het watergehalte in de glaswolmat en anderzijds een verschil in doorspoeling van de mat. Een snellere verversing van de voedingsoplossing in de mat zou een hogere produktie kunnen geven. Een grove poriënstructuur is dan positief omdat de zuurstofvoorzie- ning van de wortel niet in gevaar zou komen door de hoge gietfrequentie.

De eerste teelt is eind december geplant en de laatste oogst was in mei. Aan het einde van de eerste teelt zijn de watergehaltes in de matten van de verschillende behandelingen gemeten. Er waren geen significante verschillen in watergehalte. Het watergehalte in de matten lag tussen 64 en 72%.

Tot 27 april kwamen geen significante verschillen in produktie voor. Aan het einde van de teelt waren wel significante verschillen aanwezig. De lage druppelfrequentie was bij alle substraten gunstig en leidde tot meer vruchten ($p<0.05$) en gewicht ($p<0.1$) van kwaliteitsklasse 1. Ook het totaalgewicht van de geoogste vruchten was hoger ($p<0.05$).

De totaalproduktie op substraat met grote poriën was minder ($p<0.10$) dan de behandelingen op substraat met kleine poriën. Het glasvlies doek was niet van invloed op de produktie.

Na de eerste teelt zijn de glaswolmatten gestoomd en gebruikt voor de tweede teelt die half augustus startte en begin november is beëindigd. De lage gietfrequentie was niet voldoende om de wateropname van de komkommers te compenseren. Het gevolg was dat de matten uitgedroogd zijn. Het watergehalte in de matten van deze behandelingen bleef daarna laag. Door watergebrek was de produktie van de behandelingen met lage gietfrequentie significant lager dan de produktie van de behandelingen met hoge gietfrequentie.

Het totaal aantal vruchten en het aantal vruchten klasse 1 was hoger ($p>0.10$) bij substraat B. Het gewicht verschilde echter niet significant met de overige behandelingen.

Glaswol met kleine poriën gaf in de tweede teelt betere resultaten dan glaswol met grote poriën. Het gewicht en aantal vruchten van klasse 1 en het totaal aantal vruchten was significant ($p<0.10$) hoger op glaswol met fijne vezels.

De wortelverdeling is beoordeeld na de tweede teelt. De wortelverdeling was gelijkmatig in glaswol A. In glaswol B waren de wortels ook door de gehele mat verdeeld maar was de worteldichtheid duidelijk hoger in en rond het glasvliesdoek. In glaswol C zaten veel wortels onderin de mat hoger in het substraat nam de worteldichtheid af.

1) Introduction

This trial is a part of the glass wool project at the PTG in Naaldwijk. The project is financed by Isover. The aim of this research is to look at the possibilities of different types of glass wool in horticulture.

In the 1992 trials cucumbers were grown on glass wool. This report describes the set up and the results of these cucumber trials .

The aim of the experiments was to determine the influence of the water to air ratios in the root zone of glass wool substrates with different physical properties on the yield of cumcumbers. The water/air ratios in glass wool substrate can be modified with different types of glass wools. Thick glass fibres give, at the same density of the substrate, bigger pores in the substrate than thin glass fibres. The size of the pores affects the physical properties of the substrate. Small pores keeps the water stronger then big pores. Substrates with big pores contain less water and more air than substrates with small pores (at the same pressure head). A higher leaching fraction give more refreshing of the nutrient solution in the glass wool. In well aerated glass wool with big pores a high leaching fraction may give a increase of the yield.

Another method to increase the air content in the rootzone is to modify the root distribution in the slab. For this we used a substrate with glassfibre film at 2.5 cm from the bottom of the substrate. The function of glassfibre film is to modify the root distribution in the substrate. Due to gravity root growth is downwards oriented. The roots can't penetrate the glassfibre film so they stay in the upper layer of the slab. The air supply is better because there is less water in the rootzone. Therefore the orientation of the actual rootzone is better because in the upper part of the slab the water content is lower than in the bottom part. Stil the water in the bottom part is available for uptake by the roots because of capillarity of the glassfibre.

2) Materials and method

2.1) Materials

Cucumber plants of common cultivars Ventura (first crop) and Jessica (second crop) were used with a plant density of 1.4 plants per m^2. The substrate volume for each plant was 6.75 litres. Before starting both crops the slabs were completely saturated. Three glassfibre substrates were combined with two irrigation-frequencies (normal and high).
The used glassfibre substrates were:

- A) Curled glassfibre with thin fibres, density 35 kg/m^3, small pores.
- B) Curled glassfibre with thin fibres, density 35 kg/m^3, small pores and with a glassfibre film at 2.5 cm from the bottom of the slab.
- C) Curled glassfibre with thick fibres density 35 kg/m^3, big pores.

Before the start of the second crop the slabs were sterilised at 120^{o}C.

2.2) Method

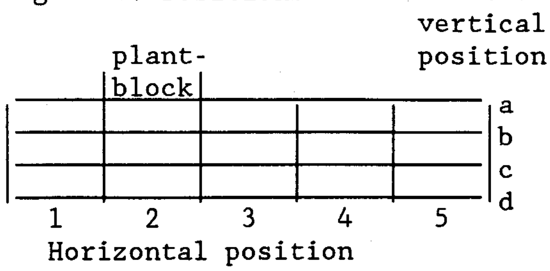
2.2.1) Irrigation frequency and drain holes
The irrigation frequencies were based on the calculated transpiration of the plants.
At the high frequency 200 ml water was given after uptake of 50 ml by the plant, the leaching fraction being 0.8 (of the gift). The normal irrigation frequency had a leaching fraction of 0.3, 200 ml water was given after uptake of 150 ml water.

De distance between two plants was 90 cm. The plants were planted on one slab of 120 cm. So the slabs ended at one side of the plant at 15 cm. The slabs were drained at three places, at 0, 60 and 120 cm.

2.2.2) Harvest
The fruits were harvested three (stem fruits) or two times (later in the crop) a week. At each date the fruits were classified and the weight and number of the fruits in each class was determined.

2.2.3) Root distribution
The root distribution was studied after the second culture in samples of 15 * 10 * 2.5 cm. The surface of 15 by 10 is analysed. Root density was visually determined by classifying each root observation in a scale from 1 to 10. Many roots were classified as 10 and no roots as 1.
The positions where roots were determined are the horizontal lines in figure 1.

Figure 1: Positions of the root density observations.



2.2.4) Chemical analyses of the nutrient solution

Frequently samples of nutrient solution in the slab were analysed at the B.L.G.G. in Naaldwijk.

2.2.5) Water content in the slabs

To measure the water content in the slabs two methods were used. At both dates a water content meter was used. In November the water content was also determined gravimetrically.

3) Results

3.1) Water retention curves

The water retention curves for all types were determined two times: Once at the start and once after two crops. The results are given in figures 2 to 7. In appendix A the data are given in tabular form.

Glassfibre substrate C with a coarser structure had, at the similar pressure head, a lower water content than substrate A and B. The water retention curves changed during the crop. The modifications in water content are given in table 3 of appendix A. At pressure heads between -7.5 and -10 cm the water content of used substrates was lower than the new substrates. The water content of the used substrate at pressure heads between -12.5 and -20 was higher than of the new substrates.

It is not sure that the physical properties of the used glass wool are more regular at different pressure heads. A possible hypothesis is that the upperlayer became dryer and the underlayer (with many roots) became wetter during the culture. At the high pressure heads the upperlayer and at lower pressure heads the underlayer would influence more the watercontent of the 7.5 cm thick glass wool.

3.2) Yield

Two crops were planned for 1992. The second crop, however, had to be replanted twice very soon after the start because of pests and diseases. Therefore, the second crop could only start on 18 august after the system was disinfected. Results of the first crop are shown in figures 8 to 11. The data of these figures are given in appendix B.

Until 27 April no significant differences in Yield occurred. At the end of the first crop (25 may) the low irrigation frequency gave signifcantly more fruits ($p<0.05$) and weight ($p<0.10$) of quality 1 than high irrigation frequency. The total weight was also significantly higher ($p<0.05$) for the low irrigation frequency.

In the second crop the high irrigation frequency gave a significantly higher yield (2 October $p<0.05$, after 29 October $p<0.01$) than the low irrigation frequency.

The substrate with small pores (with and without glassfibre film) gave in both crops a significantly better production than the substrate with big pores. Till 25 April the number of first quality fruits, the total weight (both $p<0.05$) and the weight of first quality ($p<0.10$) differed significantly. In the second crop till 29 October the number of first quality fruits($p<0.05$), at 12 november the number and weight of first quality fruits and the total number of fruits($p<0.10$) differed significantly.

The glassfibre film did not influence the weight of the yield but in the last crop the number of fruits was significantly ($p<0.10$) higher on the substrate with glassfibre film.

The quality of the fruits and the mean fruit weight differed not significantly for all treatments.

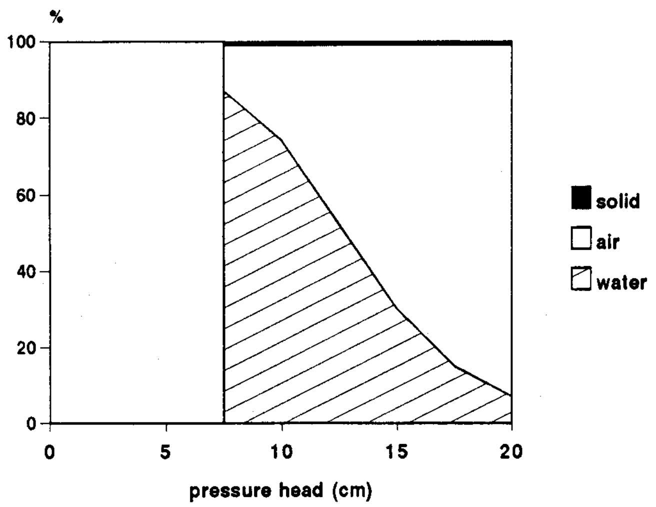


Figure 2: new glassfiber with small pores.

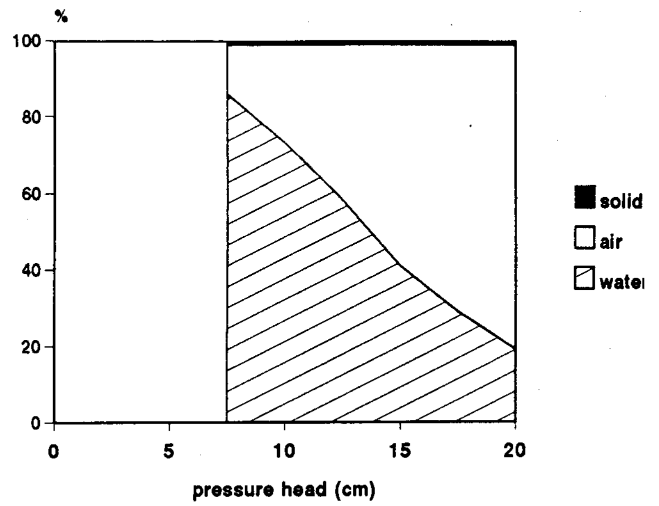


figure 3: glassfiber with small pores after two crops

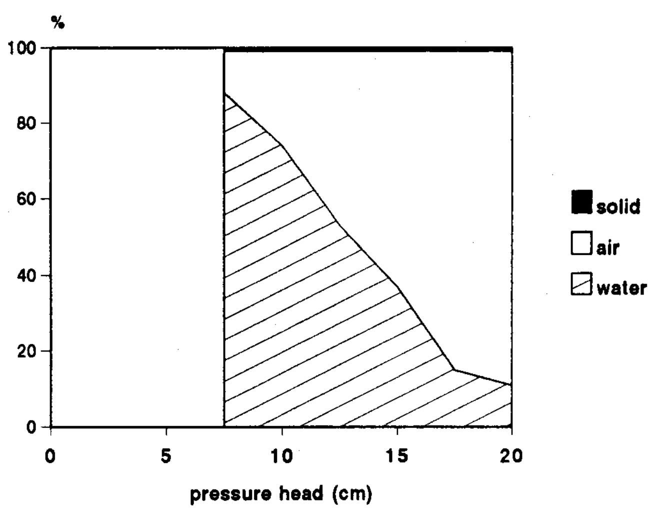


figure 4: new glassfiber with small pores and film.

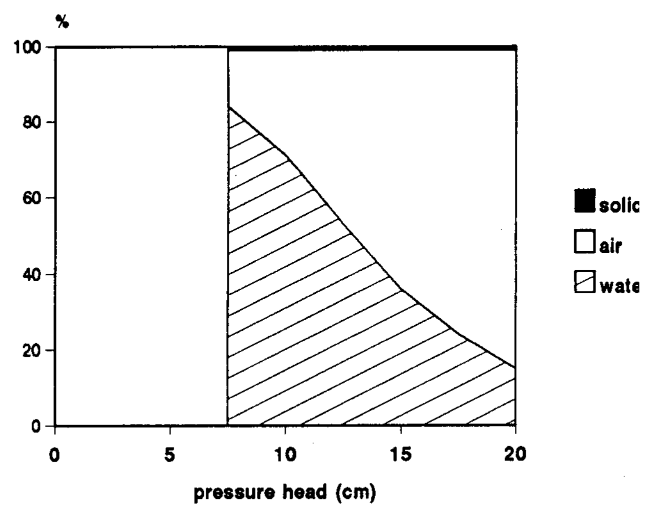


figure 5: glassfiber with small pores and film after two crops

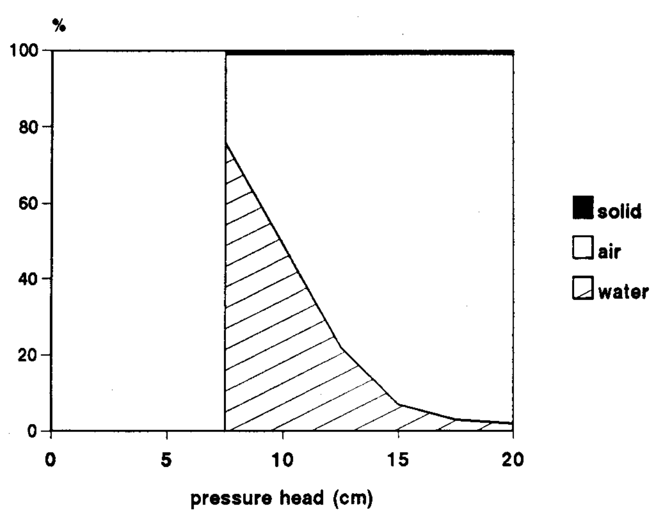


figure 6: new glassfiber with big pores

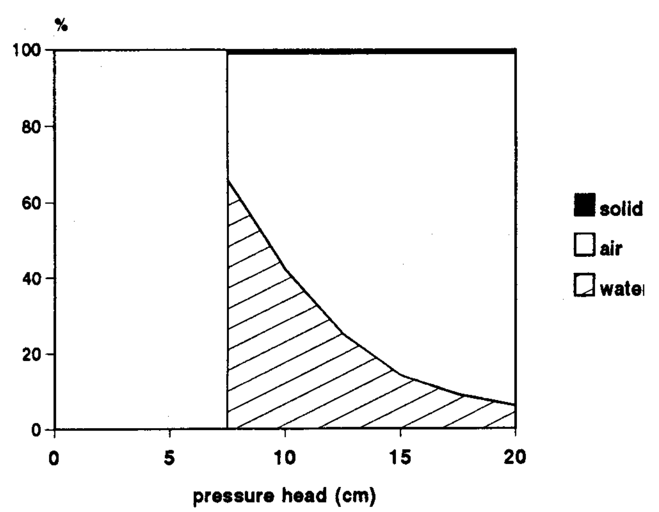


figure 7: glassfiber with big pores after two cultures

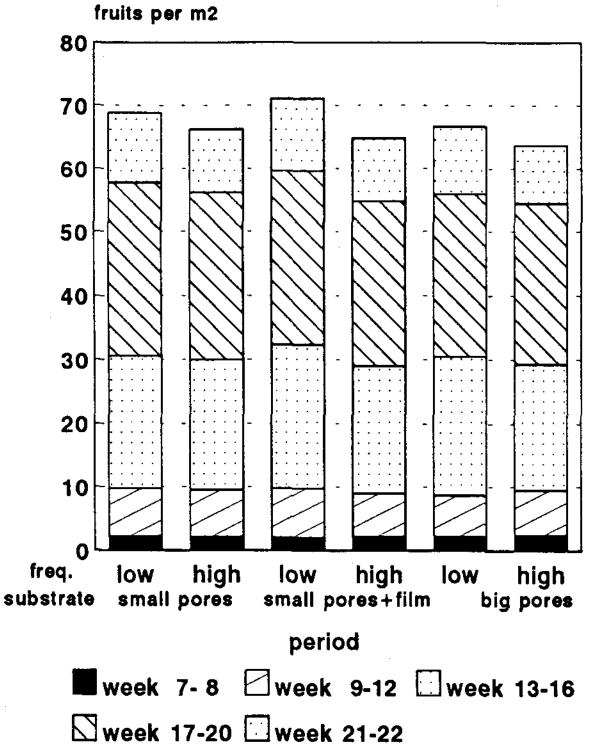


figure 8: total yield of the first crop;
number of fruits per m2

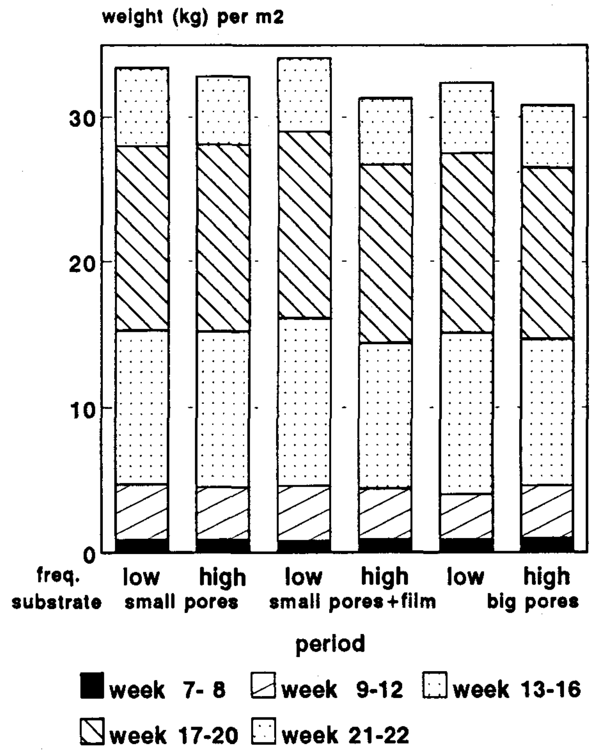


figure 9: total yield of the first crop;
weight of the fruits per m2

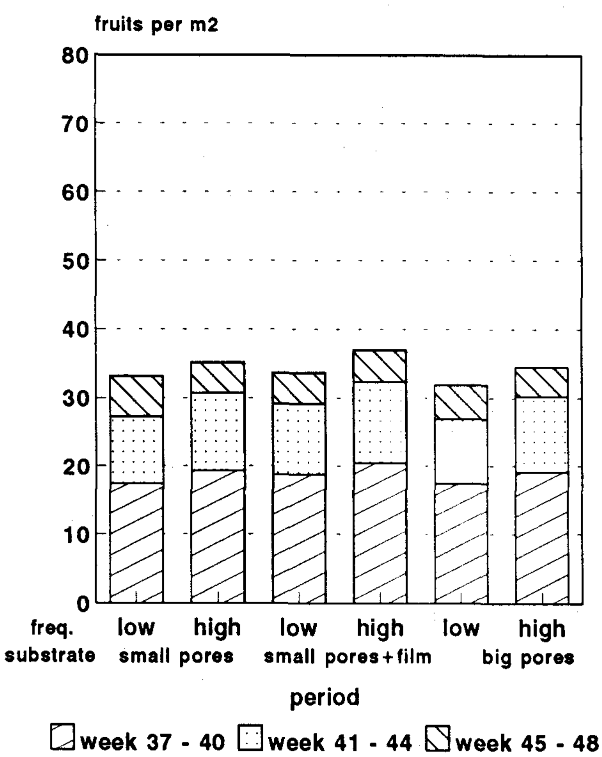


figure 10: Total yield of the second crop;
number of the fruits per m2

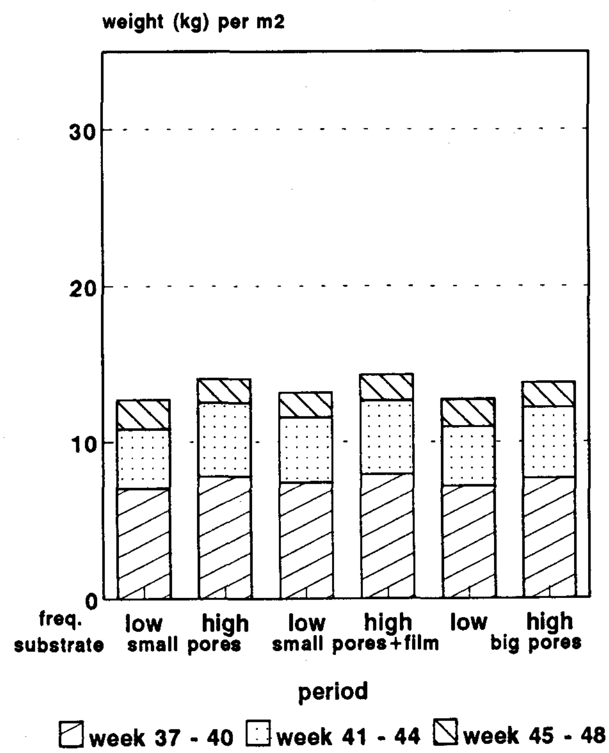


figure 11: total yield of the second culture;
weight of the fruits per m2

3.3) Root distribution (second cucumber crop)

The results are given in figures 12 to 17 and tabels 9 and 10 in the appendix C. The glassfibre film had a very local influence on the root distribution in the slab. In the film (vertical position 3) many roots are formed but the root quantity in the bottom layer (vertical position 4) was the same for the treatments with and without film. The mean value of the root density at 5 mm under and 5 mm above the fibre film was in the same order of magnitude of that of the root density at position 3 in substrate A.

The high irrigation resulted in a bigger quantity of roots, particulary at the horizontal positions 1 and 3.

The substrates with small pores had more roots in the upper layers (positions 1 to 3) and less roots at the bottom (position 4) than the substrate with big pores.

3.4) Water content in the slabs under crop conditions

The water content in the slabs was measured on 20 July 1992 and 16 November 1992. The results are given in table 4 of appendix A.

The water/air ratios in the treatments were not constant during the season. In July neither the substrates nor the irrigation-frequency resulted in different water contents of the slabs. In November a low water content was measured for the substrates with low irrigation frequencies.

In November the substrate with big pores had a significantly lower water content than the substrate with small pores. The glass wool film did not influence the water content of the slab at the low irrigation frequency. At the high irrigation frequency there was a significant influence of the glass wool film on the water content.

The used watermeter gave a good indication of the differences of water content the slabs. Absolute values determined with this meter were rather dubious.

3.5) Chemical analyses of the nutrient solution

The results of the chemical analyses are shown in appendix B. The evolution of the ions Na^+ and Cl^- is important because the low uptake of these ions by plants. The concentration of Na and Cl is presented in figure 18.

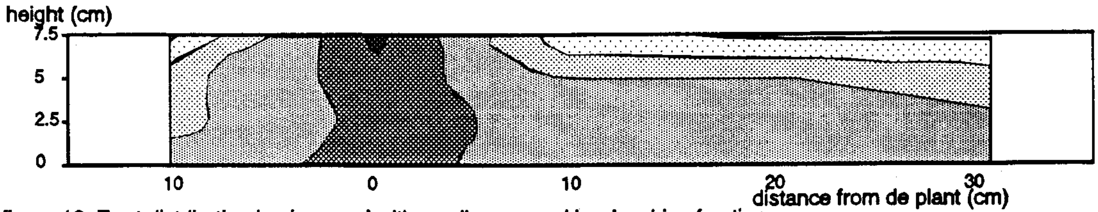


figure 12: Root distribution in glasswool with small pores and low leaching fraction

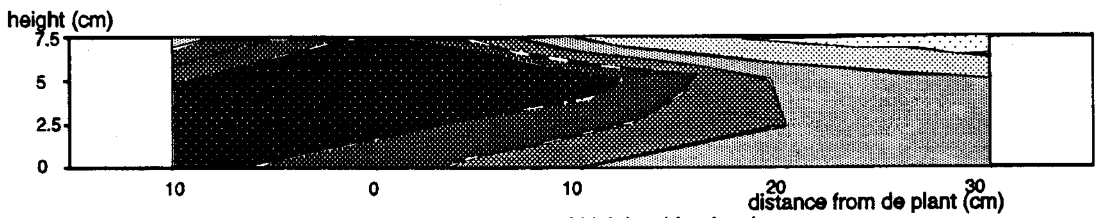


figure 13: Root distribution in glass wool with small pores and high leaching fraction

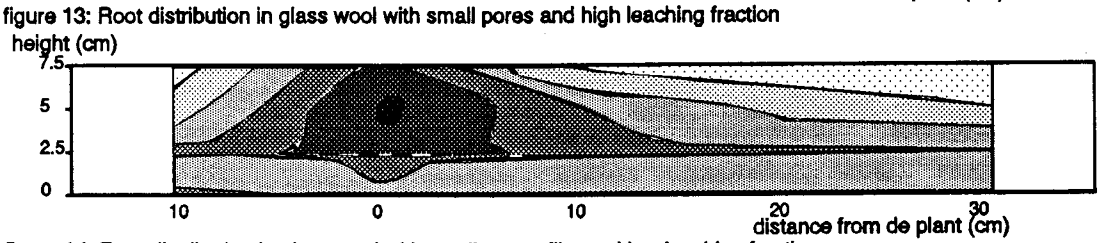


figure 14: Root distribution in glass wool with small pores, film and low leaching fraction

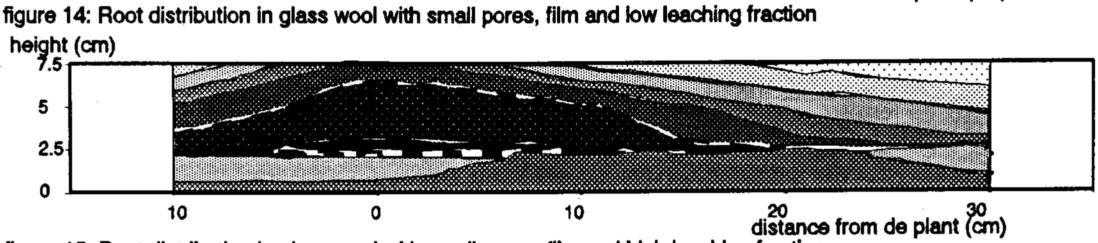


figure 15: Root distribution in glass wool with small pores, film and high leaching fraction

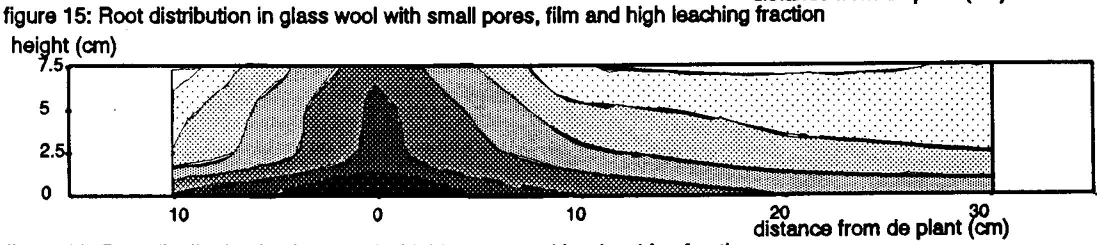


figure 16: Root distribution in glass wool with big pores and low leaching fraction

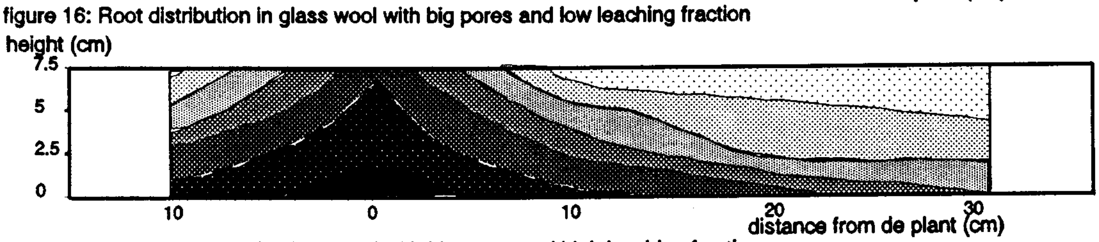
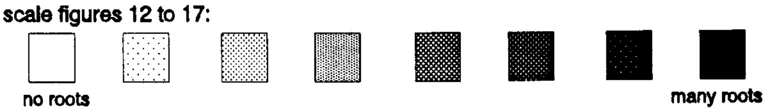


figure 17: Root distribution in glass wool with big pores and high leaching fraction

scale figures 12 to 17:



4) Discussion

4.1) Water to air ratio in the substrate

The water content of the glass wool substrate with small pores (figures 2 to 5) was lower at the same pressure-heads than those of the substrate with big pores (figures 6 and 7). In the first crop neither the irrigation frequency nor the different physical properties of the glass wool substrates influenced the water content measured on 20 June (table 4) in the slab. In the second crop there was variation of water content between the treatments. The water content in glass wool substrate with big pores was lower than in the glass wool substrates with small pores. These results were in agreement with the results of the water retention curves. The difference in water content of the glass wool substrates with and without glass wool film at the high irrigation frequency seems strange. An explanation for this is not available. The water retention curves are similar for these two substrates. At the lowest irrigation frequency the water supply wasn't sufficient during some periods so the substrates dried out; the water retention in the substrates of this treatments was low.

The water content in the substrates was the result of the physical properties and the drying out of the substrates.

4.2) Root distribution.

The root density was the highest for the high irrigation frequency in any position of the slab (tables 9 and 10). The cause of this difference is not clear. It could be that roots died due to the lack of water (van Goor, intern verslag nr. 17, Proefstation Naaldwijk, 1988). But root growth can also be stimulated under the wet conditions, a shortage of oxygen may lead to a shorter and more branched root system (van Goor 1988).

The pore size in the substrate influenced the root distribution in the vertical direction. In the substrate with small pores most roots were in the middle(positions b and c) of the substrate. In substrate with big pores many roots were found directly under the slab (position d).

The film had a very local influence on root distribution. The root density in the film at position c was very high. The quantity of roots determined at position c' (mean value at 5 mm under and 5 mm above the film) was lower than the quantity of roots in the film and in the same order as the root quantity in position 3 of substrate A. Beside the high root density in the glass wool film itself, the glass wool film did not influenced the vertical root distribution.

4.3) Yield

The high irrigation frequency gave lower results for all the treatments. Even for the glass wool substrate with big pores the yield was lower at the high irrigation frequency. In other trials results in the same direction were found. Continued trickle irrigation in a cucumber crop on rockwool in a gutter system gave a significantly lower yield (Jaarverslag Proeftuin Noord-Limburg 1984 deel 2). In a trial with roses on rockwool there was a tendency that many small applications (20 cc/plant) gave less flowers than a few big applications (80 cc/plant) of water at the same leaching fraction (Jaarverslag Proeftuin Vleuten 1987). Gerbera grown in aggrofoam with ebb/flow showed a tendency of less flowers at a two times higher irrigation frequency than normal (Van Os and Van den Berg).

The reason for this fenomenon is not clear. The difference between the high and low irrigation frequency may be the volume of the substrate that dries out between two irrigation periods.

At high irrigation frequency 50 ml was consumed by the plant before the next application of 200 ml. At the low irrigation frequency 150 ml of the application of 200 ml was consumed.

Two possible hypotheses for the increased yield are :

A) When the volume of wateruptake is higher the penetration of fresh air into the substrate is more pronounced. The maximum concentration of oxygen in water($20^{o}C$) is 8.3 mg/l. The concentration of oxygen in fresh air is much higher: 300 mg/l. Between two irrigation periods of the low frequency the uptake of water pulled 150 ml air with 45 mg oxygen into the substrate. The same volume of substrate gasses disappeared during one application.

B) After irrigation air channels are blocked by water filled pores. Water consumption by the plant will restore the air channels in the substrates. These channels are important for the gas diffusion in substrate. Short after irrigation potential gas transport is low. At a higher frequency the gas transport is hampered more often.

In the second crop we did not find the same results. Because the low irrigation frequencies weren't sufficient, the plants suffered from water, and therefore the yields of these treatments were probably reduced.

In both crops glass wool substrate with big pores gave a lower yield than the glass wool substrate with small pores. The root distribution in substrate with big pores was poorer. Most roots were found at the bottom of the slab, the plant utilised only part of the total substrate volume. The botom layer of the substrate is always wet, so probably the air supply was not optimal. This can be the reason why the high irrigation at the first crop did not give a better production.

In glass wool with small pores the roots were well distributed in the slab. In the upperlayer the supply of oxygen, water and ions was probably optimal for root function.

5) Conclusions

* In these trials glass wool with small pores gave a more homogeneous root distribution and also a better production than substrates with big pores.
* glass wool with big pores combined with a higher irrigation freqency did not improve yield in this trial.
* The average water to air ratio in 7.5 cm thick glass wool is not a good indication for the growing conditions in glass wool.
* Besides the water to air ratio in glass wool the root distribution in glass wool seems very important.
* When the irrigation was sufficient the difference in water content between the substrates with small and big pores was small.
* A regular leaching fraction was more important to maintain the water retention than the irrigation frequecy.
* Insufficient irrigation at the lowest frequency gave a decrease of the maximum water content in the substratee and lower yield compared to the higher frequency.
* The influence of the irrigation frequency was not clear but it seems safe to allow a minimum water uptake by the plant between two applications.

6) Recommendations

* A determination of the root distribution in glass wool is necessary to determine the utility of the glass wool.
* In this trial only two types of glass wool were used. Other types with smaller poresizes and pore sizes between the two types in this trial should be taken in consideration. Bigger poresizes do not seem promizing.
* Glass wool with small pores in de upperlayer and big pores in de underlayer could improve the root density in the upperlayer and the air supply in the underlayer.
* A better distribution of the irrigation water at the surface of the slab could be an possibility to improve the root distibution within glass wool with big pores. When the root distribution is more homogeneous the plant roots would benefit the whole glass wool volume
* When the irrigation is lower than the wateruptake by the plant a part of the glass wool may dry out irreverseble. The maximum water content of the slab after this situation is lower. The higher air content in this situation might be favourable for root function and plantgrowth. More information is needed about the drying out effect on root distribution, water distribution and water transport in a 7.5 cm slab.
* More research is desired to confirm the advantage of the large water uptake by the plant between two applications.

Appendix A : Data of the water retention curves

table 1: Water content of new substrates at different pressure heads

Pressure head / Substrate	Watercontent(%) -5cm	-7.5cm	-10cm	-12.5cm	-15cm	-17.5cm	-20cm
small pores	-	87	74	52	30	15	7
with film	-	88	74	53	37	15	11
big pores	-	76	49	22	7	3	2

table 2: Water content of used substrates (after 4 crops of cucumber) at different pressure heads

Pressure head / Substrate	Watercontent(%) -5cm	-7.5cm	-10cm	-12.5cm	-15cm	-17.5cm	-20cm
small pores	95	86	73	58	41	29	19
with film	93	84	71	53	36	24	15
big pores	86	66	42	25	14	9	6

table 3: Changes in water content of firstly used substrates during one growing season

Pressure head / Substrate	Watercontent(%) -5cm	-7.5cm	-10cm	-12.5cm	-15cm	-17.5cm	-20cm
small pores	-	- 1	- 1	+ 6	+11	+14	+12
with film	-	- 4	- 3	0	- 1	+ 9	+ 3
big pores	-	-10	- 7	+ 3	+ 7	+ 6	+ 4

table 4: Water content under crop conditions in percents of the total volume

		substrate description+frequency: small pores		small pores+film		big pores	
Date:	Method:	low	high	low	high	low	high
20- 7	Watermeter	67	72	67	67	66	64
16-11	Watermeter	53	81	58	72	35	60
16-11	Gravimetric	42	77	49	68	32	60

Appendix B : Yield

table 5: Number of fruits per m^2 in each period of 4 weeks

substrate-description	water-supply	period week 7- 8	week 9-12	week 13-16	week 17-20	week 21-22	total week 7-22
small pores	low	2.3	7.5	20.8	27.1	11.1	68.8
	high	2.2	7.3	20.5	26.1	10.1	66.2
small pores with film	low	2.1	7.7	22.6	27.2	11.4	71.0
	high	2.3	6.7	20.0	25.8	10.0	64.8
big pores	low	2.3	6.4	21.8	25.4	10.7	66.6
	high	2.5	7.0	19.8	25.1	9.3	63.7

table 6: Yield in kg per m^2 in each period of 4 weeks

substrate-description	water-supply	period week 7- 8	week 9-12	week 13-16	week 17-20	week 21-22	total week 7-22
small pores	low	0.9	3.8	10.6	12.7	5.4	33.4
	high	0.9	3.6	10.7	12.9	4.7	32.8
small pores with film	low	0.8	3.8	11.5	12.9	5.1	34.1
	high	0.9	3.5	10.0	12.3	4.6	31.4
big pores	low	0.9	3.1	11.1	12.4	4.9	32.5
	high	1.0	3.6	10.1	11.8	4.3	30.7

Second crop: start 18 August 1992; last harvest 12 November 1992.

table 7: Number of fruits per m^2 in each period of 4 weeks

substrate-description	water-supply	period week 37-40	week 41-44	week 45-46	total week 37-46
small pores	low	17.4	9.8	5.9	33.1
	high	19.3	11.4	4.4	35.1
small pores with film	low	18.7	10.4	4.5	33.6
	high	20.4	11.9	4.6	36.9
big pores	low	17.4	9.5	5.0	31.9
	high	19.1	11.1	4.3	34.5

table 8: Yield in kg per m^2 in each period of 4 weeks

substrate-description	water-supply	period week 37-40	week 41-44	week 45-46	total week 37-46
small pores	low	7.01	3.82	1.89	12.72
	high	7.77	4.76	1.52	14.06
small pores with film	low	7.38	4.19	1.60	13.17
	high	7.89	4.75	1.65	14.30
big pores	low	7.15	3.82	1.77	12.74
	high	7.65	4.57	1.58	13.80

Appendix C : Root distribution

table 9: Horizontal root distribution :

substrate-description	Frequency	position' 1	2	3	4	5
small pores	low	2.4	4.6	2.9	2.4	2.4
	high	5.4	6.2	4.6	3.2	2.7
small pores with film	low	3.2	5.1	3.6	3.1	2.9
	high	4.5	5.8	5.3	4.3	3.6
big pores	low	2.2	5.5	2.9	2.2	2.0
	high	4.2	6.6	3.9	2.8	2.4

'position 1 is at the left side of the plantblok
position 2 is under the plantblok
position 3 to 5 are at the right side of the plantblok

table 10: Vertical root distribution :

substrate description	Frequency	position' a	b	c	d
small pores	low	1.7	3.2	3.4	3.5
	high	3.0	5.3	5.0	4.3
small pores with film	low	2.2	3.5	4.6	3.9
	high	2.7	4.9	6.6	4.5
big pores	low	1.5	2.4	3.0	5.0
	high	2.3	3.4	4.4	5.9

'position a is the surface of the substrate
position b is at 2.5 cm from the surface
position c is at 5 cm from the surface
position c'is the mean value at 5.5 and 4.5 cm from the surface
position d is at the bottom of the substrate

Appendix D : Chemical analyses; concentration of nutrients, EC and pH in the substrate solution.

Table 11: Major nutrients

irrigation-frequency	nutrient date	NH4	K	Ca	Mg	NO3	SO4	P	HCO3
low	06-02-92	0.1	13.7	11.4	5.2	38.0	4.5	1.9	0.1
	20-02-92	0.1	15.6	12.8	7.1	43.8	6.9	1.6	0.2
	02-03-92	0.1	10.8	10.1	6.1	31.0	6.2	0.3	1.2
	23-03-92	0.1	12.4	9.9	5.7	31.1	7.4	0.3	0.5
	07-04-92	0.1	5.1	8.0	4.2	16.8	5.9	0.0	0.3
	22-04-92	0.1	2.0	5.5	2.3	8.6	4.7	0.0	0.2
	04-05-92	0.1	4.7	6.4	3.0	14.6	3.8	0.1	0.2
	26-05-92	0.4	13.0	6.9	3.6	32.1	3.0	0.6	0.2
	10-06-92	0.1	9.5	2.6	1.9	14.7	2.7	0.1	2.2
	24-06-92	0.3	6.8	3.2	1.6	10.9	2.4	0.3	0.8
	26-08-92	1.6	10.3	5.2	2.3	15.9	4.4	0.6	4.2
	17-09-92	0.1	1.9	2.3	1.2	3.4	3.0	0.1	0.9
	14-10-92	0.1	10.0	6.6	2.5	20.0	4.4	0.6	0.2
high	06-02-92	0.1	11.5	9.2	4.2	30.9	3.5	1.9	0.1
	20-02-92	0.1	12.7	9.1	5.0	31.5	5.5	1.6	0.1
	02-03-92	0.1	12.1	8.7	4.8	26.8	5.7	0.9	0.1
	23-03-92	0.1	13.9	9.9	5.0	30.4	7.2	0.2	0.1
	07-04-92	0.1	5.4	7.7	3.5	16.4	5.1	0.0	0.1
	22-04-92	0.1	0.8	5.4	2.5	5.9	5.1	0.0	0.1
	04-05-92	0.1	4.3	7.7	3.5	15.4	5.1	0.1	0.1
	26-05-92	0.2	10.3	6.5	3.4	24.9	3.2	0.3	0.4
	10-06-92	0.1	7.2	1.7	1.6	11.0	2.2	0.1	1.3
	24-06-92	0.1	6.5	3.5	1.7	11.4	2.5	0.2	0.7
	26-08-92	1.6	10.3	5.2	2.3	15.9	4.4	0.6	4.2
	17-09-92	0.1	3.3	2.8	1.7	4.3	3.9	0.1	2.4
	14-10-92	0.1	7.9	6.6	2.6	18.3	4.3	0.4	0.1

Table 12: Minor nutrients, EC and pH.

irrigation frequency	nutrient date	Fe	Mn	Zn	B	Cu	pH	EC
low	06-02-92	23.0	20.0	17.0	89.0	1.5	6.3	5.0
	20-02-92	*	*	*	*	*	6.6	6.0
	02-03-92	50.7	10.1	27.3	135.3	2.1	6.8	4.8
	23-03-92	68.0	15.0	40.0	127.0	3.1	6.5	5.0
	07-04-92	78.0	15.0	37.0	99.0	3.2	6.6	3.3
	04-05-92	66.0	9.7	29.0	56.0	2.8	6.2	2.4
	26-05-92	22.0	1.0	27.0	11.0	1.1	6.4	3.8
	10-06-92	24.0	1.0	20.0	26.0	0.6	7.1	2.5
	24-06-92	22.0	1.5	15.3	24.0	0.9	6.9	2.1
	26-08-92	28.0	14.0	9.2	47.0	1.3	7.3	3.3
	17-09-92	57.3	3.3	3.8	20.7	0.7	6.6	1.4
	14-10-92	70.0	7.6	6.5	21.0	1.0	6.3	3.4
high	06-02-92	17.0	15.0	15.0	76.0	1.3	5.8	4.2
	20-02-92	*	*	*	*	*	6.1	4.6
	02-03-92	33.0	6.5	24.7	105.0	2.2	6.0	4.3
	23-03-92	92.0	16.0	40.0	100.0	2.9	5.0	4.9
	07-04-92	63.0	14.0	33.0	79.0	2.4	6.2	3.0
	22-04-92	90.0	9.0	44.0	86.0	3.6	6.2	1.9
	04-05-92	71.0	9.2	40.0	56.0	3.0	5.5	2.8
	26-05-92	26.0	6.1	30.0	9.0	0.9	6.9	3.4
	10-06-92	17.0	0.7	19.0	14.0	0.5	7.0	2.0
	24-06-92	19.0	1.1	15.3	28.7	0.7	6.9	2.2
	26-08-92	28.0	14.0	9.2	47.0	1.3	7.3	3.3
	17-09-92	52.7	5.5	6.7	32.7	1.1	7.2	1.9
	14-10-92	68.0	5.6	4.5	15.0	0.7	5.3	3.2