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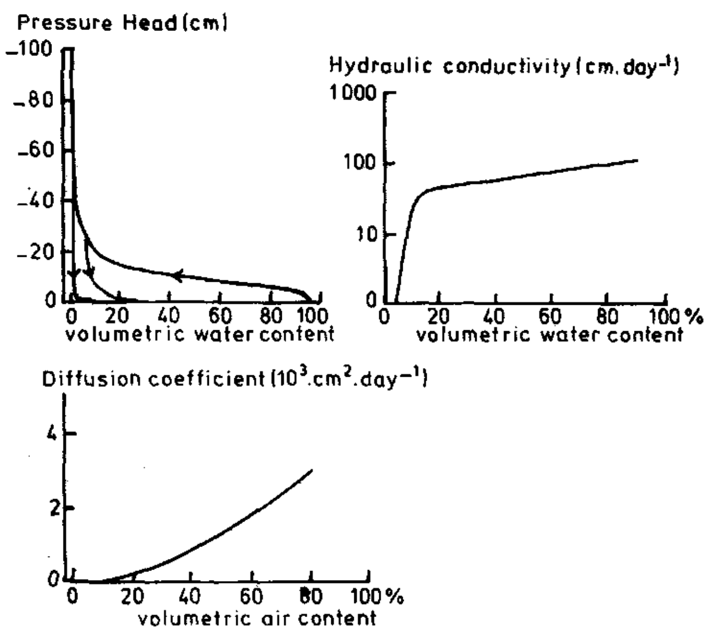
INTRODUCTION

Rockwool is an artificial medium consisting of threads of 0.05 mm and having a porosity of about 96% (Jørgensen, 1975). The dependencies of pressure head, hydraulic conductivity, and gas diffusion coefficient upon water content were measured by Willumsen (1972; see Fig. 1).

Fig. 1. Physical properties of rockwool



To wet rockwool the pressure head must be increased to near the atmospheric reference pressure head. During drying the decrease of the pressure head is more gradual. The hydraulic conductivity decreases rapidly with decreasing water content, particularly below 30%.

The common mat thickness of 7.5 cm provides a reasonable balance of adequate water supply and aeration. For tomatoes and cucumbers, growers use mats that are 7.5 cm high and 30 cm wide, with the plants 45 cm apart (Sonneveld, 1980). The volume of substrate per plant is then about 10 l. This will provide a maximum of 7 l available water, which is at best enough for 2 sunny days. In practice, water and nutrients are supplied 3 to 5 times per day. Accumulation of salts in the mats can be avoided by balancing the supplies of water and nutrients as well as possible to the demands by the plants and by providing excess water for leaching (Raats, 1980). This is a difficult task and in the Netherlands growers are advised to regularly monitor the composition of the nutrient solution in the mats: pH and EC twice every week, major elements twice every month, and minor elements once every month. Whenever, as a result of discrepancies between the compositions of supply and demand, excess solutes have accumulated, extra water for leaching should be provided. The distribution of the accumulated salts will depend on the amounts of water, nutrients, and impurities supplied, on the distribution of the root activity, and on the flow pattern between drippers and drainage outlets and the degree of dispersion in the mat. The flow pattern and the dispersion will also determine the efficiency of the removal of salts by leaching with water in excess of the demand by evapotranspiration. Within limits the flow pattern can be optimized by suitable placing of drippers near the plants, and of drainage slits in the plastic underneath and along the sides of the mats. The importance of flow patterns in assessing accumulation and removal of salts is well known, on a small scale for drip irrigation (Hoffman, 1976) and on a large scale in arid zone irrigated regions (Raats, 1978).

The purpose of this paper is to present some data on the accumulation of salts and their removal by leaching. For a more detailed discussion of these and related experiments the reader should consult three reports by Van Noordwijk (1978, 1979) and Van Noordwijk and Raats (1980).

EXAMPLE OF DISTRIBUTIONS OF ELECTRICAL CONDUCTIVITY (EC), pH, AND ROOT SURFACE AREA

Figure 2 shows some measurements of EC, pH, and root surface area in an experiment with tomatoes at the Institute of Agricultural Engineering at Wageningen, The Netherlands. The samples were taken after a sunny period in June when the plants were in full production.

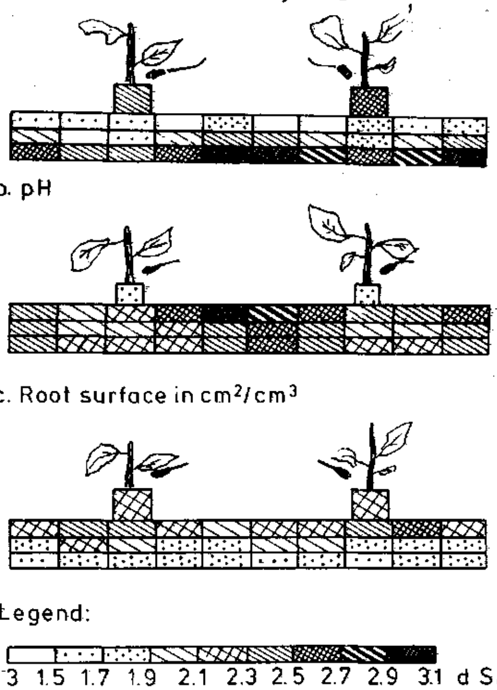
Figure 2a shows that on that day the salinity in the mat ranged from 1.3 to 3.1 d S/m (roughly 0.355 d S/m corresponded to an osmotic pressure of 100 kP). After a less sunny period in August, when the plants were in early senescence, the salinity in a wet mat was everywhere in the range of 1.7 to 2.3 d S/m and for a dry mat everywhere in the range of 1.5 to 2.3 dS/m, in both mats mostly in the interval 1.9 - 2.1 d S/m. Fig. 2b shows that the pH ranges from 5.6 to 7.4, with the highest values in the "dead zone" between the emitters. Fig. 2c shows that the root surface area decreases towards the bottom of the mat and is largest near the base of the plant stem. The rockwool could be washed out after breaking the bonds between the threads with a 1.8% solution of hydrochloric acid (Brouwer and Van Noordwijk, 1978). Some examples of intact root systems are shown in Figure 3.

Fig. 2 Distributions of E C, pH, and root surface area

a. Electrical conductivity in d S/m

b. pH

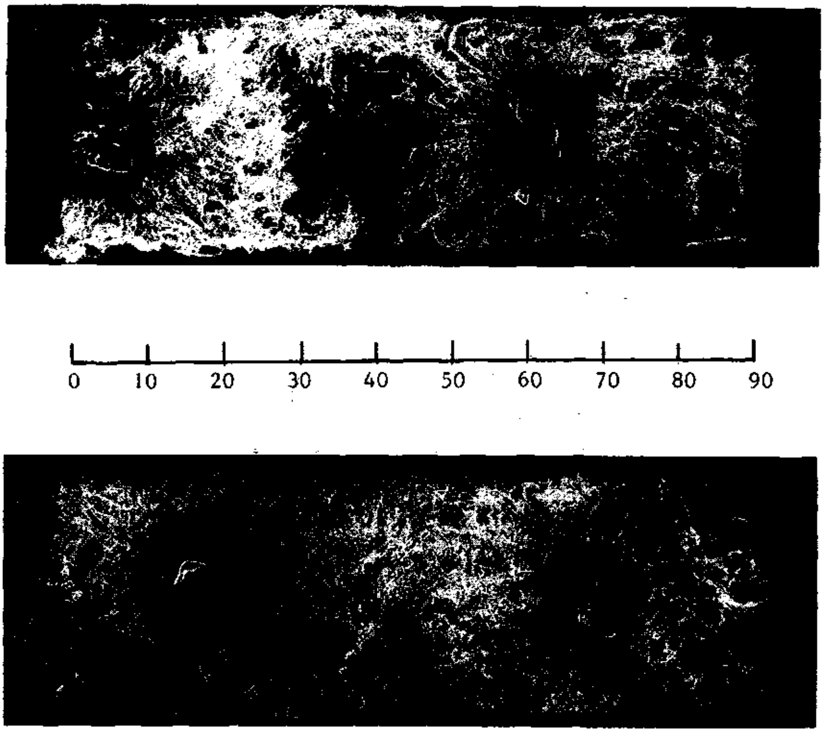
c. Root surface in cm^2/cm^3



Legend:

1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	d S/m
4.7	5.0	5.3	5.6	5.9	6.2	6.5	6.8	7.1	7.4	pH
	.25	.5	1.0	2.0	4.0	8.0	16.0			cm^2/cm^3

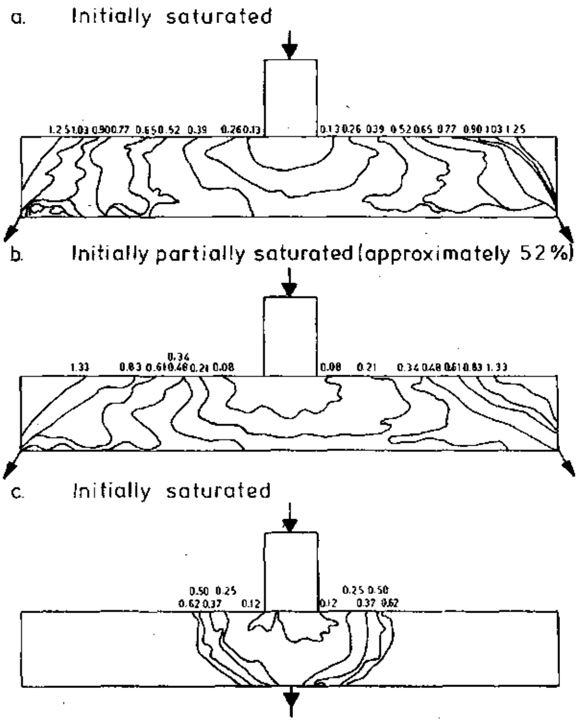
Fig. 3. View of the root system, washed out on a pinboard. The roots are concentrated around the plant blocks



LEACHING OF ACCUMULATED SOLUTES

The efficiency of leaching depends strongly on the location of drippers and drainage slits. Some aspects of this were simulated in the laboratory. Water colored with a dye (safranine) was dripped in the middle of a strip of rockwool 50 cm long. 5 cm wide, and 7 cm high. Plastic was placed underneath and, with the exception of drainage slits, along the sides to a height of 1 cm. The interface between the water originally present in the mat and the dyed water was clearly visible. The effluent was collected and the concentration of safranine was measured. Three situations were compared; the resulting interfaces at successive times are shown in Figure 4.

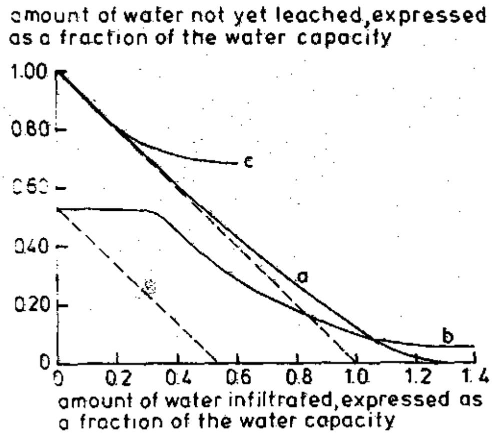
Fig. 4. Successive dye fronts for three cases. The arrows denote the drippers and the drainage outlets. The numbers on the fronts correspond to the amount of water infiltrated, expressed as a fraction of the water capacity



The interfaces remained quite sharp, i.e., piston displacement occurred. The elliptical shape is caused by the spreading in the block of rockwool on top of the mat and the fact that the layered structure of the mat implies that the hydraulic conductivity is larger in the horizontal direction than in the vertical direction (Van Noordwijk, 1979). Figures 4a and b show that a gradually increasing tilt of the interface and some preferential movement of water between the mat and the plastic underneath caused drainage of dyed water long before all the water originally present in the mat was displaced by dyed water. Figure 4b shows that in a mat which is initially partially saturated, the early spread of the dyed water is rapid, but that the "dead corners" persist for a long time. Figure 4c shows that a short-circuit between dripper and drainage outlet leads to inefficient leaching.

On the basis of a general theory for multidimensional, convective transport of solutes by steady flows, one can infer how much of the water initially present in the mat is still present in the mat after a given inflow (Raats, 1978). Figure 5 shows three curves corresponding to the three leaching patterns shown in Fig. 4.

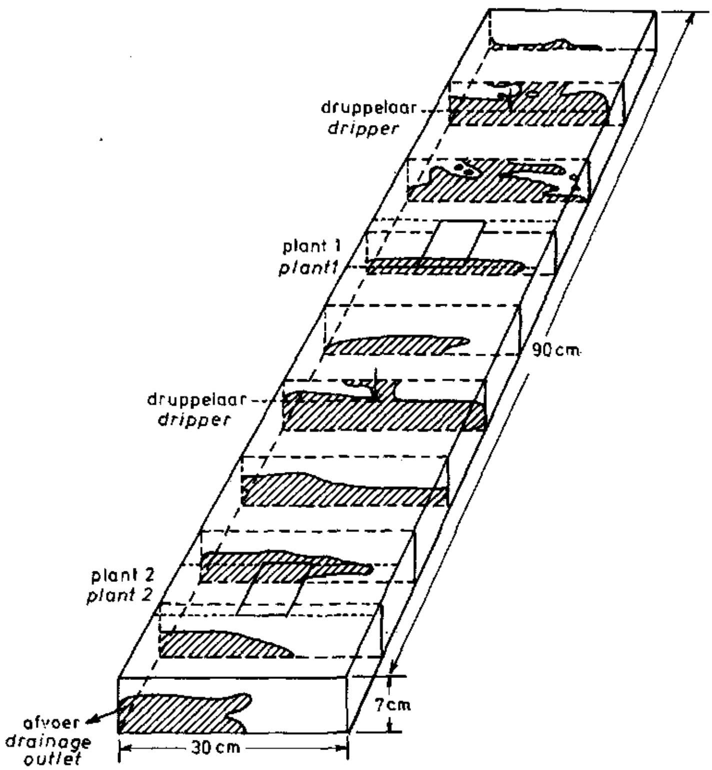
Fig. 5. Leaching efficiencies corresponding to the three patterns shown in Figure 4.



Curve a shows that after an inflow equal to the total amount of water initially present in the mat only 12% of the water initially present in the mat has not yet been leached out. Curve b shows that in the initially partially saturated mat outflow only starts after adding 30% of the water capacity. Note that after adding 120% of the water capacity, more of the initially present water remains in case b than in case a. Curve c shows that with the drainage outlet directly underneath the emitter the dyed water starts to appear already after adding 20% of the water capacity and that after adding 50% of the water capacity almost no further leaching of the water initially present in the mat occurs.

To complement the measurements reported above for the narrow mat, the infiltration of a safranine solution was repeated in a mat of regular size. After adding 170% of the water capacity, the mat was cut in sections of 10 cm each. The safranine fronts are shown in Figure 6.

Fig. 6. Detailed view of the distribution of the infiltrated water in a mat.



The upper part of the mat remained quite dry and was colored with safranine only directly around the emitter. Near the drainage outlet the dyed water had invaded only about half the width of the mat.

CONCLUSION

In rockwool culture accumulation of excess salt is not uncommon. It can be avoided by regular monitoring and, whenever necessary, taking corrective actions. As a result of the quite uniform pore size, the degree of dispersion in rockwool is small. The efficiency of leaching depends mainly on the relative placement of drippers and drainage outlets.

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SUMMARY

In rockwool culture excess supply of nutrient and lack of sufficient leaching can rapidly lead to localized accumulations of salts. Such accumulations could limit root growth and depress yields. Excessive accumulation of solutes in the mat can, even under the best circumstances, only be avoided by regular monitoring the composition of the nutrient solution in the mat and, whenever necessary, taking corrective actions. Experiments with water, colored with dye, showed that, as a result of the quite uniform pore size, the degree of dispersion in rockwool is small. Therefore, the efficiency of leaching accumulated salts will mainly depend on the relative placement of drippers and drainage outlets.