CLOSED SOILLESS GROWING SYSTEMS IN THE NETHERLANDS: THE FINISHING TOUCH

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Keywords: greenhouse horticulture, substrates, emission, water quality, water quantity, fertilizers

Abstract

This paper gives an overview of the latest developments in closed soilless growing systems in the Netherlands, where growers are obliged to invest in environmently friendly cropping systems, in order to comply with new legislation. Subjects of discussion will be the reasons for regulation, the growers' reaction to the proposed legislation, the methods to comply with legislation and related problems such as the availability of good water, the systems applied and the developments in the disinfection of nutrient solutions. For the latter, the interest of growers in the possibilities of slow sand filtration to disinfect the nutrient solution will be mentioned.

In the last ten years there has been an awakening of environmental consciousness in society. Agriculture and horticulture have had to face their polluting aspects, too, such as the leaching of nutrients, the emission of pesticides and the waste of materials such as plastics and substrates. Initial legislation was rather rough ("all growers should change to closed systems") and not based on research. Later, forced by court judgements and social pressure, new regulations (the Waste Water Disposal Decree) have set a timetable for all nurseries to adopt specific measures in order to decrease the leaching of water and fertilizers to the environment. The recirculation of drain water and the collecting of rainwater have become compulsory for substrate growers. On the other hand, recirculation via the soil and the traditional drainage system has been approved as a "closed" substrate system. For soil-bound crops, maximum water supply and collecting rainwater will be compulsory.

In the last few years, low market prices have shown very clearly which closed sytems were profitable and which were not. As a consequence, a discussion arose about the benefits for the environment of the new regulations and the costs for the growers. There were few new developments in growing systems, as the growers' first point of attention was economic survival. This year, 1996, prices have been better and the growers are again looking for possibilities to improve the quality of their systems.

In the Netherlands, it has always been said that disinfection of the recirculating nutrient solution is a must for long-term crops to avoid a disaster due to an outbreak of root diseases. However, existing sterilizing systems are not always applied, mainly because of the high costs. Now, developments in disinfection equipment focus on the removal of pathogens without a complete sterilization of the nutrient solution. Investigations of the prospects of slow sand filtration as a cheap, robust disinfection method have proved its feasibility only on a small scale.

Now, it can be seen that the development and application of closed soilless growing systems is approaching maturity in the Netherlands. On the other hand, developments in

other countries are still going on, where it should be possible to avoid the mistakes made in the Netherlands. An environment-conscious cultivation improves the prospects of protected cultivation in our advanced society.

1. Introduction

At the moment that the Dutch government produced its first memorandum to decrease environmental pollution caused by farmers and growers (Agricultural Structure Memorandum, 1989), the discussion about the polluting aspects of the leaching of fertilizers in open soilless systems had already started. Experiments with recirculation of the nutrient solution were being executed at the time, but then, the environment was added as a new argument. As a consequence, developments in closed systems were accelerated. A safe, sustainable and competitive horticulture sector (National Environmental Policy Plan, 1989) should be achieved, and in 1994 not less than 80% of glasshouse vegetables and potplants and 30% of flowers should be grown detached from the subsoil, while 30% of the area should recirculate the nutrient solution (Agricultural Structure Memorandum, 1989). Now, the rough statements of those years look somewhat old-fashioned and non-realistic as we consider them with our present knowledge. The research projects started as a result of the above-mentioned memoranda, very quickly proved that the statements were not feasible for all growers or for all crops. On the contrary, they sometimes proved to be incompatible with each other. Ruijs (1994) showed that "sustainable" and "competitive" do not always match, especially not in an economic sense. Van Os (1994) summarized the earlier research: there are a few factors which determine whether a change to closed systems may be economic: such as the number of plants per m^2 and a potential increase in production and space utilization. In general, a combination of these factors determines the financial result. With a low number of plants per m^2 it is mostly economic to invest in (closed) soilless growing systems. Tomato and cucumber are such crops. If the plant density is high and there is no potential increase in production, the financial result will be negative, as higher investments and extra annual costs cannot be compensated. Lettuce and radish are examples. If space utilization is low (carnation, rose, alstroemeria) closed soilless growing systems may be beneficial. Even the rather expensive rolling benches show good prospects for these crops (Ruijs, 1994 & 1996), because of the increased yield.

Pressure by the growers, results of research and court judgements, have induced new views. Changing to soilless cultures was not always feasible economically, closed systems have sometimes emissions of nutrients and the approval of certain soil-grown methods as sustainable growing system has moderated the policy of the Agricultural Structure Memorandum. Additional legislation was formulated with the aim to reuse the superfluous water flow as much as possible and to minimize the leaching to the environment. Concrete targets were drawn up to be achieved before 2000. Within this period, an evaluation of the measures will be executed.

In this paper an overview will be given of the new legislative targets and the consequences they have to the growers. Besides, related problems such as the availability of good water, the systems applied and the developments in the disinfection technology will be discussed. An outlook on the future will conclude this paper.

2. Legislation as a steering factor for investments

In 1994 the Waste Water Disposal Decree was passed. The aim was to decrease the use of water and fertilizers, the promotion of the reusing waste water and the sanitation of the leaching remainder. For this, specific regulations were made for substrate growers and for soil growers. In table 1 an overview is given. The various measures will be discussed in the next paragraphs.

2.1 Measures to be taken by all growers

For two years now, growers have been obliged to record the use of water, the amount of drain water and the amount of water leached to the environment. For this, water meters have been installed. Besides, the use of fertilizers and pesticides has to be recorded. The drain water to be leached has to be analysed four times a year on sodium, nitrate and phosphate. Now, control of all flows is possible, which will be controlled by the water quality managers.

The collection of the "first flush", the first 0.5 mm of rain after 48 hours of dryness, is a measure to avoid the leaching of pesticides to the surface water (Van den Tempel, 1995). Condensation water contains remnants of pesticides which were sprayed on the greenhouse roof. It flows partly in the "condensation gutter" and partly into the rain gutter. The first rain shower cleans the rain gutter, and consequently contains pesticides. For this, a special "first flush" basin must be built with a size of 5 $m^3.ha^{-1}$ for substrate growers and 30 $m^3.ha^{-1}$ for soil growers. The water in this basin should be reused on the nursery as soon as possible to create new space for the next "first flush". If the basin has been filled and it is still raining, a bypass, built before the basin, will conduct the water flow to the surface water. This water does not contain any pesticides.

The grower has no objections against reusing condensed water, except when his greenhouse gutters contain zinc (galvanized steel). In that case reuse leads to an accumulation of zinc in the supply water, resulting in the necessity for extra leaching. Normally, galvanized steel rainwater gutters are coated on the water-collecting side, but not on the side exposed to the greenhouse. The chemically unbuffered condensed water dissolves zinc, which is collected in the rainwater basin. In new greenhouses, rainwater gutters and condensed water gutters are strictly separated to avoid any problems. Alternatively, there is the choice of using aluminium instead of steel to avoid zinc problems.

Growers have made great objections against this "first flush" measure. It is their opinion that it leads to high investments, while there is no benefit to the environment. A more fundamental objection is that after 48 hours of dryness the rainwater basin is empty enough to collect the "first flush". A substrate grower uses 30-50 m^3 per ha per day. An extra collection tank is unnecessary. The water quality managers do not agree with a direct flow to the rainwater basin, because of the possibility of an overflow to the surface water. The growers argument against this is that, if the rainwater basin overflows, the water quality is extremely good and free from pesticides, as an enormous dilution has already taken place. Another objection of the growers is their need to change the nutrition scheme continuously, because of the quality differences between rainwater and "first flush" water. The discussion about this subject has not yet finished.

2.2 Measures to be taken by substrate growers

Regulations for the recirculation of the drain water have not met much opposition from the substrate growers, especially when roses are excluded. Rose growers have been allowed to change to a closed system only at the time they change their crops. This is mostly happening between 3 and 5 years. Therefore, the date was set at November 1998. An exception is also made for orchid growers, who hardly use fertilizers and hardly produce any drain water.

The quality of good supply water is based on its sodium content. If supply water is available with a sodium content lower than 1 $mmol.l^{-1}$ the provision of rainwater storage is not compulsory. As can be seen in table 2, the quality of rainwater is the best. Sometimes well water has a similar quality, but this quality can only be found in the eastern and northern parts of the Netherlands. Most of the greenhouses are found in the western part. Here, well water as well as surface water and tap water contain too much sodium. For these growers rainwater storage is compulsory with a capacity of at least 500 $m^3.ha^{-1}$. Based on an average rainfall of 750 mm per year, approx. 50% of it can be used. A storage capacity of 1500 $m^3.ha^{-1}$ is mostly recommended, then 75% of it can be used. For a 100% utilization, a capacity of 6000 $m^3.ha^{-1}$ is needed (KWIN,1995).

For overground storage of rainwater metal silos or earth basins are mostly used. Silos have a number of advantages above basins, such as a better space utilization (more capacity per m^2), less transpiration because of a smaller surface, and they are easier to cover to avoid algae growing. Disadvantages of silos are the fixed round shape and the higher investments for storage capacities of more than 1250 m^3. Earth basins can easily be built on non-used pieces of land of variable sizes.

Under special conditions rainwater can be stored underground (fig. 1). The water is infiltrated in a sand layer which is enclosed by an impervious ground layer, through which the groundwater flow is small. These conditions do not occur on many places in the Netherlands. The main advantages are the saving of space, the large capacity and the absence of algae. Disadvantages are the high investments, the lack of control on the amount in stock and a variable, impredictable output (70% on average).

On several places many growers are cooperating in a joint supply water project. In the province of Drente two similar projects are based on water-filled sand pits which are filled by rain and groundwater and have no connection with the surrounding surface water. The total amount of water available is able to supply approx. 400 ha of greenhouses without damaging the surrounding nature. Now, all growers with a total greenhouse area of less than 200 ha, are cooperating.

The remainder flow to be leached if sodium figures exceed certain levels (table 3), should be conducted to the sewage system. The main problems are that many growers are not connected to the sewage system (absent in many rural areas) and that the capacity is too small, because it has been designed for domestic waste water only. Besides, if one grower wants to drain to the sewage system, in fact all growers need to do that. Problems with the accumulation of sodium and the shortage of good quality supply water will appear for all at the same moment. In that case extreme capacities are necessary. Connection to the sewage system will be compulsory, but only for small waste flows such as dripping or percolation water from substrate waste and scrubbing and cleaning water. Permission will be given for disposing of drain water with high sodium contents to the surface water (table 3).

2.3 Measures to be taken by soil growers

For soil growers rainwater collection can take place in a similar way as performed by substrate growers. Until now, hardly any soil grower uses rainwater, because of the high investment and the absence of the necessity to use good quality supply water. Consequently, all growers need to make the relevant investments.

Recirculation of drain water is quite new. Practical experiences originate from open substrate systems, these growers have not made investments in closed systems, but used their additional drainage system. Just recently, this method of recirculation has been approved as a closed, sustainable growing system (see 3.2).

The demand to increase the efficiency in water and fertilizers use will result in introducing a maximum water supply for soil growers. There are different figures for different crops (Niebeek & Leunissen, 1996). Once-over harvestable crops, grown at low temperatures, will be permitted to use 8,600 $m^3.ha^{-1}.year^{-1}$ in 1997. Perpetually harvestable crops, grown at high temperatures, are allowed to use 11,400 $m^3.ha^{-1}.year^{-1}$. Other crops, such as once-over harvestable crops, grown at high temperatures, perpetually harvestable crops, grown at low temperatures and mixed crops are allowed to use 10,000 $m^3.ha^{-1}.year^{-1}$. These figures are based on average transpiration rates increased with approx. 30 % drain.

In the recently presented provisional guidelines, a distinction is made between polluting and non-polluting nurseries. Polluting are those nurseries, which leach more than 300 kg nitrogen per ha per year. For these nurseries recirculation will be compulsory, if they can decrease the leaching of nitrogen by more than 150 $kg.ha^{-1}.year^{-1}$. Theoretically, recirculation will be demanded for crops such as chrysanthemum, rose, gerbera, carnation, radish, lettuce, cucumber, tomato, sweet pepper and aubergine. Recirculation will whether actually be compulsory will depend on the measurements and analyses of drain water in 1996 and 1997 on the nurseries involved.

3. Developments in growing systems

Developments in growing systems have taken place in two directions for the last few years. On the one hand, there are improvements in detail in the existing systems. Experiments have been executed with traditionally soil grown crops. On the other hand, recirculation via the soil drain system has been approved as a "closed system", but application is limited because of the high requirements at which nurseries should fulfil.

3.1 Closed soilless growing systems

The technical demands for closed growing systems to decrease environmental pollution are described by Van Os (1994). Multi-year use of substrates and materials decrease the environmental load and the annual costs. By 1994, many growers still had open systems and investments had to be made to change to closed systems. Due to low market prices growers do not only take into account low annual costs, but also low investments. Therefore, drain profiles made of polypropene, polyvinylchloride or polyethylene foil with a drain pipe are preferred (fig. 2). Sometimes polypropylene containers with multi-year substrate slabs are used, but very often single-year slabs enveloped with polyethylene foil are preferred (fig. 2). The environmental aspects are of much less importance than the economic aspects.

The last few years, research has focused on developing and testing closed systems for greenhouse crops which were still cultivated in soil (Ruijs, 1996), such as chrysanthemum, carnation, freesia, alstroemeria, radish and lettuce.

By growing chrysanthemums on ebb-and-flow systems and on aeroponics, higher yields were achieved compared with soil growing. The yields obtained in NFT, substrate beds and drip irrigation on polypropene mats were lower or similar. A better space utilization has resulted in an increase in the yields of lettuce, alstroemeria and freesia. Shortening the cultivation time is feasible for lettuce and freesia. Results for carnation were very variable. After many disappointing results it was possible to grow good-quality radish on sandy substrate beds. Here, the watering strategy is of great importance to achieve nicely coloured tubers and to avoid the formation of side roots.

In general the growing systems are not economically feasible for the above-mentioned crops. Except for alstroemeria on rolling benches, there are reasonable prospects.

3.2 Recirculation via the additional drainage system

The possibilities of recirculation via the additional drainage system depend on the specific hydrological situation in the surrounding of the nursery (Ruijs & Van Os, 1991; Voogt & Korsten, 1995; Korsten & Van Moolenbroek, 1996). The following situations occur (fig. 3):

1 *Groundwater level is higher than the depth of the drains*. In these situations there is a large amount of drain water as a result of a large water supply (exceeding transpiration), seepage or infiltration. Reuse of seepage water depends on the sodium content, which may be very high (>10 $mmol.l^{-1}$). Infiltration water is mostly coming from the ditches and has lower concentrations of sodium and nitrate. Both will influence the quality and quantity of the drainage water. This situation mostly occur in the polders of the western part of the Netherlands. Most of the drain water is collected during winter, when transpiration is very low. To optimize the use water storage tanks will have to be built.

2 *Groundwater level is equal to the depth of the drains*. This is a more or less optimum situation, at which there is hardly any seepage, infiltration from ditches or downward seepage. This situation does not occur very often. The amount and composition of the drain water only depends on the amount and composition of the water supplied.

3 *Groundwater level is lower than the depth of the drains*. This is the normal situation in sandy areas in the eastern and southern parts of the Netherlands. Mostly, there is no drainage system. If a drainage system is available, all percolation water can be reused, but the quantity is rather small. Besides, there is a big chance of downward seeping.

Recirculation via the additional drainage system is permitted for crops in open soilless systems and for soil-grown crops. It is only possible in the above-mentioned situations 1 and 2, though highly dependent on the quality and quantity of the seepage water and the infiltration from ditches.

The composition of the drain water not only depends on the quality of the seepage water or the infiltration water, but also on the quality of the water supplied in relation to the transpiration rate. Voogt (1995) reports on very variable rates of efficiencies of nitrogen fertilizers for tomato, radish and chrysanthemum, being 25-30%, 55-100% and 30-80%, respectively. However, there are possibilities to increase the efficiency of nutrients. It is most important to relate the water supply to the transpiration of crop and soil by measuring the water contents of the soil (see chapter 4). Besides, the application of fertilizers will have to be adapted. Here, the supply of fertilizers has to be connected to the demands of the crop. Often a base fertilization can be omitted (Voogt, 1995).

The quality of the drain water is also influenced by the use of pesticides. Runia (1996) reports about insecticides and fungicides which are found in the drain water. Often, the figure found is higher than the permitted value.

The quantity of the drain water also depends on the local situation and the amount supplied in relation to the transpiration rate. The amount of seepage water can hardly be influenced and so can the amount of downward seepage. The amount of infiltration can be influenced by increasing the drain level to the water level in the surrounding ditch by introducing a turnable device on the outlet of the drain system (Hamaker & Bloemhard, 1995). For soil cultures, a rise in the groundwater table may cause problems, especially in winter; the problems for substrate cultures are less severe. Improvements of the water supply system and the watering strategy will be discussed in paragraph 4.

In summary, it can be said that possibilities for the recirculation of drain water via the additional drainage system are limited and depend very much on the local situation.

4. Water supply and watering strategy

New supply systems are being developed, and new watering strategies examined which allows increased efficiency of water use. Now, drip irrigation systems can be bought, the pipes of which do not empty after watering. In the drippers a membrane is built, which opens and closes at a certain pressure. The effect is that all drippers start at the same moment and that emptying of the pipe and, as a consequence, leaching at one spot, does not take place. This is of great importance for both substrate and soil growers. The latter are increasingly installing drip irrigation instead of or in combination with sprinkler irrigation. Although guidelines can be given to improve the uniformity of sprinkler irrigation (Heemskerk & Schotman, 1996), overhead watering has other disadvantages. Flower crops such as chrysanthemum or freesia and vegetable crops such as lettuce may suffer quality losses due to overhead watering at the last growing stage. This is a reason to stop watering long before the end of the growing period. At that moment all water for the plants need to be stored in the upper soil layer. Using drip irrigation, watering can be extended till harvesting time as much as the plants need.

Improvements in the layout of the drip irrigation system were described by Gieling et al. (1995). The main problems in the standard layout are the time delay and the fall in pressure as a result of the increasing distance from the pump. Comparing the standard situation (fig. 4) with the new "Tichelmann" approach, which has been in use for heat technology for a long time, has shown that these problems are solved. This is especially interesting in cases that the nutritional scheme has to be changed or that pesticides have to be applied. By the Tichelmann approach, it is within seconds that the new solution is divided all over the system, whereas the standard situation cannot avoid a delay between the first and the last dripper of many minutes or even a few hours. In winter time this delay means that the last dripper used to get its fresh solution not before the next day.

Recently, research has been started to increase the efficient use of water and fertilizers by changing the watering stategy (Balendonck, 1996). The idea is based on the concept of keeping the water available for plants in the top layer of the soil where the plant roots are located. Beneath this layer there will be an inactive soil layer which acts as a buffer between root zone and groundwater. Thus, topsoil and groundwater will be hydrologically detached. To achieve these wet and dry layers, sensors are needed to measure the water contents. Based on the frequency-domain measuring method, new sensors will be designed. One device consists of more sensors measuring soil water content, soil water tension, EC and temperature at several depths. Besides, a water management method will be developed based on new algorithms and a model.

All developments in water supply and strategy are focused on a more efficient use of water and nutrients and on the avoidance of leaching.

5. Disinfection of the nutrient solution

The change from soil-grown crops to soilless growing has not resulted in a disappearance of soil-borne pathogens. In open soilless systems the risks were not yet so large, but with the introduction of closed systems, the risk of spreading soil-borne pathogens all over the nursery increased dramatically. Since 1987 heat treatment, the first disinfection equipment, appeared on the market (Van Os et al., 1988; Runia et al., 1988). It was followed by a large variety of methods (Ontsmetten, 1996). Some have remained on the market, some have not. From the beginning, disinfection equipment have been seen as a kind of insurance premium: there is a chance you get a root disease, but often there are no problems at all. In table 4 a summary is given of the different methods which can be used (Runia, 1996).

Heat treatment is the most frequently used method. Growers find it reliable and easily understand the principle. The amount of gas to heat the water (1 m^3 gas per m^3 water) is a disadvantage. Ozonization is the most expensive option and for that reason not very popular. For this reason hydrogen peroxide is often used as a cheaper alternative, but the performance is less. Hydrogen peroxide is a weak oxidator. Application of an activator (a weak acid) improves the performance quite well. Investigations are still going on. Therefore, a practical recommendation cannot be given. The working of UV radiation is dependent on the transmission of the water. Therefore, it is sometimes mixed with supply water from the rainwater basin, which increases the required capacity of the installation and also the price. There is no difference in performance between low and high-pressure lamps. The risk that pathogens can hide behind suspended particles is considered a big disadvantage.

Research as to the performance of slow sand filtration continues. Phytophthora and pythium are eliminated, but not fusarium and tomato mosaic virus (Runia et al., 1996). A flow rate of 100 $l.m^{-2}.h^{-1}$ increases the performance, and so does selecting a finer sand (0.15-0.35 mm; D_{10} < 0.4 mm) (Van Os et al., 1996). Practical installations often use flow rates of 300-700 $l.m^{-2}.h^{-1}$, while the grain size is mostly 0.2-2 mm. The chemical contents of water is not changed by the sand filter. Filtration with lava granules is based on a rather high flow rate (350 $l.m^{-2}.h^{-1}$) while air is simultaniously added at the bottom. As a consequence, the water bubbles continuously. The method is investigated and will be compared with slow sand filtration at the Research Station in Naaldwijk.

Membrane filtration (microfiltration, ultrafiltration, nanofiltration and reverse osmosis) can eliminate pathogens or even ions. The practical application of disinfection is stagnating, because of unreliability of the membranes and clogging of the pores. Reverse osmosis is mainly applied to supply water, additional to rainwater. The method is expensive and bound by extensive regulations (Omgekeerde osmose, 1996). Perhaps, a new generation of membranes will open better prospects (Ohtani, 1996).

6. Further decrease of environmental pollution in the future

The present legislation (Pollution of Surface Water Act and Waste Water Disposal Decree) concentrates on existing nurseries. Now, approx. 30 % fulfil these regulations, the others still have to make investments. These regulations will result in an enormous benefit to the environment, being an 80% reduction in emissions to ground and surface waters (Bouwman et al., 1996).

For the future the employers in the horticultural sector asked themselves how further improvements for the environment could be achieved to realize a status of "least polluting country in protected horticulture". Bouwman et al. (1996) have concluded in their report to answer this question, that the biggest benefit to the environment would be to break down all greenhouses older than 15 years (30% of the total area) and to rebuild large-scale greenhouses in new, well equipped areas. In this case, one looks at the effects of emissions of nutrients, energy, pesticides and waste. New, large scale greenhouses decrease the input of energy by 35%. Then, a 45% increase in energy efficiency per unit product can be achieved as well as a further reduction in emissions of pesticides and nutrients. Measures to be taken include the use of heat/power contraction and waste heat of power plants, centralized supply of CO_2, a well-dimensioned sewage system and a centralized installation for the purification of water for horticultural purposes. Such newly built greenhouses, fulfilling the environmental demands, should get a "green label" for recognition and approval. Growers' associations started negotciations with the government and with local authorities to solve rural planning problems and to subsidize these plans.

A further increase in scale is also proposed by the National Investment Bank (Van Oosterhout, 1996) to meet international competition. In a research project commissioned by the Minister of Agriculture they conclude that the size of flower and vegetable nurseries should be at least 6 ha and 10 ha, respectively. Then, the cost price can be lowered by 30%. A number of 300-500 of such major nurseries can supply the European market. Besides, there is space for 500-1000 nurseries of 1-2 ha for the local market. As a consequence, many growers would have to stop business. Growers do not think yet it is necessary to scale up to this size, but it is clear that new greenhouses will be larger.

7. Conclusions

Legislation with concrete targets for soil and soilless growers forces them to make investments to increase the efficiency of water and fertilizer use and to decrease emissions to the environment. The most important measures to be taken are the recording of water, fertilizer and pesticide uses, recirculation for substrate growers, rainwater storage, first flush equipment and connection to the sewage system. These measures have proved to result in an enormous benefit to the environment.

There are hardly any newly developed closed growing systems. Growers who grow crops (tomato, cucumber, sweet pepper, rose, gerbera) which can be economically grown on (closed) soilless systems, choose the cheapest system for the short term, preferring low investments to low annual costs. For the other crops (lettuce, radish, chrysanthemum, carnation, freesia) there are no economically feasible systems. As a consequence, these crops continue to be grown in soil. Only alstroemeria has reasonable prospects for an economic change to a soilless system with rolling benches.

The prospects for recirculation via the additional drainage system are rather poor. Possibilities depend on the local situation, where the drain water level varies between 60 and 100 cm below ground level and salty seepage, infiltration or downward seepage is at a minimum level.

A more efficient use of water and fertilizers is also feasible by improving the quality of the watering system and by performing a change in the watering strategy. The use of sensors for to measure the water content of a substrate or the soil may decrease leaching to ground and surface waters.

Excellent and expensive disinfection equipment (heat treatment, ozonization, UV radiation) are available to disinfect the nutrient solution. Cheaper systems (slow sand filtration, lava filtration, hydrogen peroxide with activator) do not eliminate all pathogens. Slow sand filtration eliminates phytophthora and pythium.

The years to come will be characterized by a scaling-up of nurseries in newly planned areas to achieve a further decrease in emissions of energy, nutrients and pesticides. Scaling-up will be the only way to compete and to become the "least polluting country in protected horticulture".

In the Netherlands a good water quality and a sufficient water quantity throughout the year are required to realize high yields with an excellent internal and external quality. An efficient use of water is the only way to decrease environmental pollution by nutrients and pesticides.

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Table 1: Regulations of the Waste Water Disposal decree and when they are effective.

All growers	
registration of use of water, fertilizers and pesticides	Nov. 1994
sampling of waste water	Nov. 1994
first flush	Jan. 1997
condensation water of zinc gutters	Jan. 1998
Substrate growers	
recirculation of drain water	Nov. 1996
recirculation roses	Nov. 1998
rainwater storage	Nov. 1996
connection to sewage system	Nov. 1996
Soil growers	
recirculation	Jan. 1998
rainwater storage	Jan. 1997
maximum water supply	Jan. 1996/1997
connection to sewage system	Jan. 1998

Table 2: Sodium content of several kinds of supply water.

supply water	Na content ($mmol.l^{-1}$)	supply water	Na content
rainwater	0.1 - 0.5	well water	0.2 - > 10
tap water	1.6 - 3.2	reverse osmosis water	< 0.1
surface water	2.0 - 8.0		

Table 3: Sodium content in drain water above which disposal to surface water is permitted (Ontwerp, 1993).

Crop	Na content drain water ($mmol.l^{-1}$)	Crop	Na content drain water
tomato	8	rose	4
sweet pepper	6	carnation	4
cucumber	6	gerbera	4
aubergine	6	anthurium	3
melon	6	cymbidium	1
courgette	6	others	5
strawberry	3		

Table 4: Disinfection equipment to eliminate soil-borne pathogens from recirculating nutrient solutions.

Method	Dosage	Active against pathogens
heat treatment	95 °C for 30 s	all pathogens
ozonization	10 g ozone per m^3 for 1 h	all
UV radiation	250 $mJ.cm^{-2}$	all
Slow sand filtration	100 $l.m^{-2}.h^{-1}$; D_{10} <0.4mm	phytophthora, pythium
Membrane filtration	--	all
Lava filtration	?	?
Hydrogen peroxide + activator	?	?

D_{10}: 10% of the weight fraction is smaller than 0.4 mm

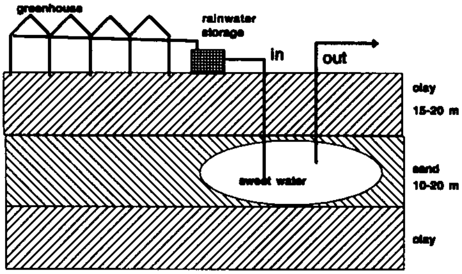

Fig. 1: Underground storage of rainwater

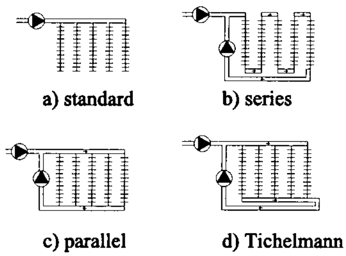

Fig. 4: "Tichelmann" approach for the trickle irrigation system

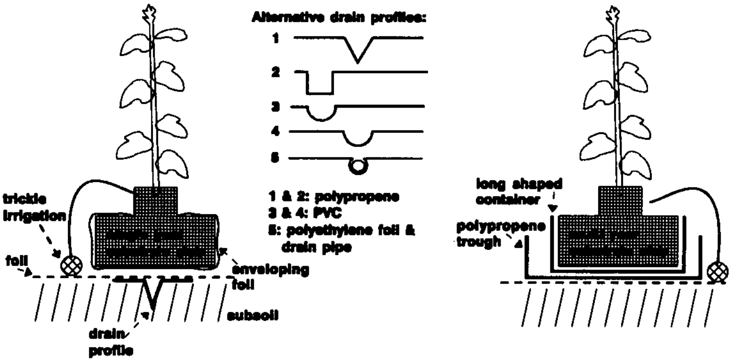

Fig. 2: Closed systems with drain profiles and with a sustainable long-shaped container

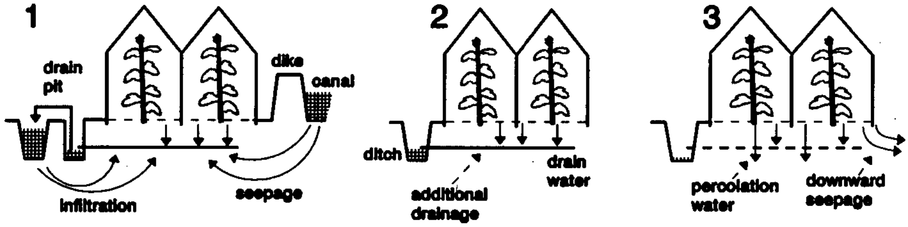

Fig. 3: Recirculation via the additional drainage system: 1 groundwater level is higher than, 2 groundwater level is equal to and 3 groundwater level is lower than the depths of the drains.