PHYTOPATHOLOGICAL ASPECTS OF CLOSED IRRIGATION SYSTEMS

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INTRODUCCION

European and in particular German growers have to struggle with environmental programs, public concern, drastical decrease in the number of available pesticides and high costs for manpower and energy. Some of these problems may be solved by soilless cultivation and/or recirculating irrigation systems.

For pot plant cultivation closed subirrigation systems (troughs, flooding benches) are widely used in European greenhouses, in Germany in an increasing extent also for the outdoor production of pot plants and woody container plants. As far as soilless culativation is concerned open systems are still predominant in cut flower and stock plant production. The hesitant introduction of soilless, closed irrigation systems may be due to high investments and growers' fear of spreading diseases.

A closed irrigation system is defined as one in which losses of water, nutrients and pesticides are widely avoided thus preventing pollution of soil or ground water. Depending on the path of water movement, recirculating irrigation systems can be classified as demonstrated in figure 1 (Molitor and Wohanka 1992). Case A describes systems in which nutrient solution is applied to the top and drainwater is collected after passing through the roots and the substrate, e.g. rockwool culture with trickle irrigation. Case B demostrates subirrigation systems in which the nutrient solution is applied to the bottom and soaks up into the root zone while the rest of the nutrient solution remains in the circulating system, e.g. subirrigation with pot plants. Case C represents substrate free cultivation such as NFT, plant plane hydroponic or aeroponics in which the bare root system is continually in contact with the circulating solution. The risk of disease dispersal depends to great extent on the type of irrigation system and on the water movement in the root zone in particular.

Disease risk of subirrigation systems for pot plant cultivation

Conventional overhead-irrigation of pot plants pose basically a rather high disease risk. The most important factor is splash water causing disease dispersal over short distances. Moreover, from possibly diseased plants pathogens can be rinsed out by the drainwater thus contaminating the irrigation mats etc. Organic material on the mostly moist bottom provides good conditions for pathogen development. Moreover, pathogens can easily be disseminated by surplus water streaming superficially between the plants. There is also a high evaporation rate causing high humidity thus increasing the risk of leaf diseases like Botrytis.

Some of these problems can be solved by using closed subirrigation systems. The flooding benches or troughs are rather clean and dry in the main, thus restricting the development of pathogens. Furthermore subirrigation avoids potentially hazardous splash water. But, what about the spread of pathogens through the whole system by the recirculating nutrient solution? Because the nutrient solution is only soaked up into the pots pathogens are not usually rinsed out by drainwater and therefore the recirculating solution does not become contaminated. If some propagules find their way into the circuit the propagule density is extremely decreased by dilution, settlement in the catchment tank and by the activity of antagonistic micro-organisms (Rattink *et al.* 1989). Therefore, the risk of disease dispersal by the recirculating nutrient solution can be expected to be low.

In several greenhouse experiments with different host-pathogen combinations in systems with up to 50% artificially inoculated plants we never observed a disease dispersal by the recirculating nutrient solution (Wohanka 1985). These results are in accordance with those from other authors (Krebs 1985, Rattink 1990, Sanogo and Moorman 1990) and practical experience.

But, it has to be taken into account that unsuitable flooding (water level too high, flooding time too long), improper equipment (e.g. additional irrigation mats) and poor sanitation can lead to serious contamination of the recirculating water thus increasing the disease risk. Especially with outdoor systems other and very crucial risk-increasing factors are rainfall and overhead irrigation. In such cases pathogens can be rinsed out by drainage water and spread throughout the whole system by recirculating nutrient solution. In this case, there is also a high risk of pathogen dissemination by splash water (Friedel *et al.* 1991).

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Disease risk of closed irrigation systems for cut flower and mother plant cultivation

Due to the same reasons as for the pot plant production, conventional overhead-irrigation of cut flowers and mother plants poses a rather high disease risk. Some of the risk factors can be eliminated by switching to closed irrigation systems in connection with soilless culture. Growers' experience with such systems indicated only minor problems with diseases, possibly due to the better plant hygienic conditions in comparison to soil culture. Additionally, the antagonistic activity of spontaneously establised microorganisms is considerably high in such systems. Results of our investigations have shown that mycelial growth in rockwool slabs or clay granules is strongly suppressed by antagonistic bacteria (Wohanka 1988). Trials with the "bacterisation" (*Pseudomonas spp., Bacillus subtilis*) of nutrient solutions have shown strong effects against fusarium-wilt of carnations (Obieglo *et al.* 1990, Van Peer *et al.* 1988).

Most of closed irrigation systems in cut flower or mother plant production are of type A or C as classified in figure 1. Mostly, the nutrient solution drips onto the top of a rockwool slab. After passing the root zone the drainage water is collected, mixed with fresh nutrient solution and recirculated. As a result, pathogens can be rinsed out by drainage water and transmitted to the whole system by recirculating nutrient solution (Bowe and Reinelt 1991, Davies 1981, Rattink 1983). Nearly the same situation can be observed in NFT and similar systems like aeroponics or plant plane hydroponic because the nutrient solution passes the root mats.

The high risk of disease spread in such systems is demostrated by an experiment with Phytophthora cryptogea on Gerbera in a closed system on rockwool slabs watered by trickle irrigation (see figure 2). Healthy plants were irrigated with drainwater from artificially inoculated plants. The pathogen spread with facility over the whole crop via the recirculating nutrient solution. Eight weeks after starting the experiment the first symptoms were observed. Four weeks later a 100% of the plants were infected and most of them already dead.

Means of water disinfection

Disinfecting recirculating irrigation water of systems with a high risk of disease spread (rockwool culture, NFT etc.) is considered to be a crop insurance for the culture. The decisions as to whether and how the grower disinfect nutrient solutions depend on the risks the grower is willing to take. Several means of water disinfection are available: Chemical treatments, heating, ozonisation, UV- irradiation and some filtration techniques (Runia 1991, Runia and Nienhuis 1992, Wohanka 1993).

Chemical methods have the considerable disadvantage of possible phytotoxicity. The differences between the concentrations necessary to kill phytopathogens and those that cause damage to the plant are often very small, thus problems exist with the exact dosage of the disinfectant, e.g. chlorine or other halogenic compounds. At least in Germany, chemical methods are not recommended.

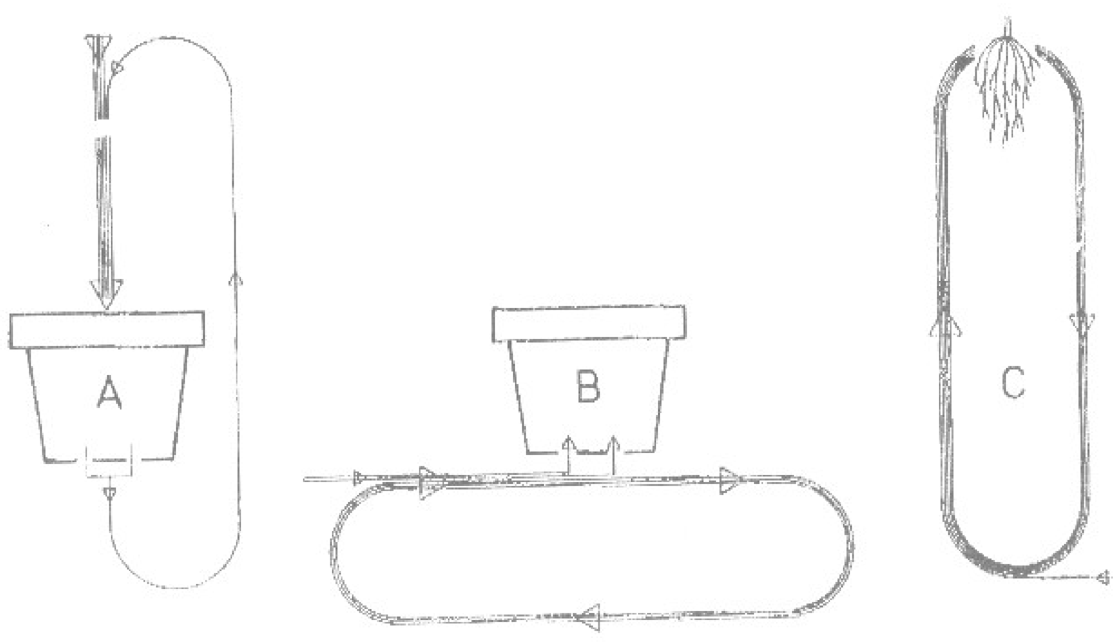

Figure 1. Basic principles of closed irrigation systems.

Heating is one of the most effective, reliable and easy to handle methods. It was developed in the Netherlands and has become established there meanwhile in some 300 horticultural farms. Drainage water passes through two heat exchangers maintaining a temperature of 95-97°C for 30 s. To avoid precipitation of calcium in the heat exchangers and tubes acidification of the nutrient solution (pH 4) is necessary. However, that system requires a high investment of more than DM 50,000.- and has a high energy consumption.

Also in the Netherlands ozonisation is used by some 100 growers. Drainage water is pumped by means of an ozone injector into a treatment tank. At the same time nitric acid is added decreasing the pH to 4 thus increasing the stability of ozone in the water. A sufficient efficacy against most of the relevant pathogens is achieved with about 10 g ozone per cubic meter and an exposure time of one hour. Organic material can decrease the effectiveness and microsclerotia are not inactivated. Moreover, ozonisation reduces the content of iron and manganese. Ozonisation needs also high investments of more then DM 50,000.

UV-irradiation is very common in community water supplies. The utilization of this technique in horticulture has to take into account the differences between clear water and a usual nutrient solution. Organic material and iron-chelates can absorb the UV light and pathogen propagules can be shadowed by larger particles. Therefore prefiltration (80- 100 μm) is necessary. High efficient systems with a minimum UV osage of about 100 Jm^{-2} need investments of the same magnitude as heating or ozonisation. Heating, ozonisation and UV-irradiation can be used economically only with relatively large cultivation areas of more than 1 ha which are not common in Germany. Therefore a working group at the Research Station Geisenheim, Germany, sought low-cost techniques which were easily adaptable to any size of cultivation area but nevertheless have a high efficacy.

Slow sand filtration is such a technique. It is one of the oldest water treatment processes and was developed more than 100 years ago. It is a simple, highly effective and the least expensive method to obtain drinking water of good quality; therefore it is currently recommended and used for community water supplies in developing countries.

The basic components of a slow sand filter are shown in figure 3. Raw water or nutrient solution passes very slowly through a bed of fine sand (see Table 1) at a filtration rate of 100-300 l/m^2h. Soon after the filter process begins, a filter skin forms on the top surface of the filter bed. It consists of organic and inorganic material and a wide variety of micro-organisms, which break down the organic matter, pathogens included. This biological activity extends through the upper layer of the sand bed, perhaps to a depth of about 40 cm. The design of the filter box varies widely. For example a corrugated iron water tank with a foil inside or a plastic container can be used. Even a simple outdoor construction, similar to an artificial pond, is possible.

TABLE 1: Quality of the filter sand

effective grain size (d_{10}) sieve opening throug which 10% (by weight) of the grains will pass,	0.15 -0.30 mm
uniformity coefficient (UC - d_{60}/d_{10}) ratio between the sieve opening throug which 60% of the grains will pass (d_{60}) and the effective grain size,	3
silt content	1%
acid solubility	5%

Several investigations with the oomycetes Pythium and Phytophthora have shown that these fungi can be eliminated completely by slow sand filtration. It was also highly effective against some other phytopathogenic fungi like *Cylindrocladium spp., Verticillium spp.* and *Thielaviopsis basicola*. A reduction rate of about 99.9% could be achieved against the microconidia of Fusarium oxysporum and a rate of 99% against the bacterium Xanthomonas campestris pv. pelargonii. Slow sand filtration also has shown some efficacy against viruses. In an experiment with the pelargonium flower break virus on geranium mother stocks in a rockwool culture 100% of the plants became infected when drainwater from diseased plants was used without slow sand filtration. With slow sand filtration only 25% of the geraniums became infected.

Application of pesticides to the recirculating irrigation water

Information about application of pesticides into the recirculating irrigation water is quite insufficient. In Germany the registration of pesticides does not usually cover the application to the nutrient solution of closed irrigation systems. However, in other European countries, the application of insecticides like oxamyl or fungicides like metalaxyl or propamocarb is a common practice. Several investigations into the possibility of adding pesticides to the circulating solution of hydroponic systems have shown that usually a lower concentration is necessary (Dekker and Runia 1991, Elsner 1988, Jamart *et al.* 1988, Price and Dickinson 1980, Price and Maxwell 1980). However, in some cases, there are still problems with phytotoxicity, even at low concentrations. With hydroponic systems the concentrations can and must be drastically lowered in comparison to the usual application to buffered media like soil or peat. Application of pesticides into the nutrient solution is also possible with the subirrigation of pot plants. Some fungicides

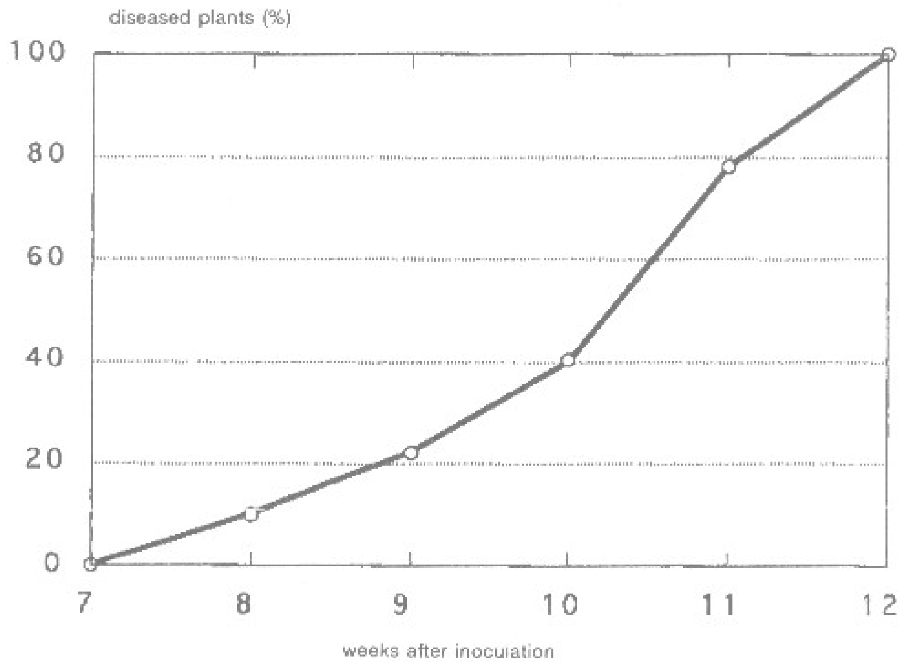

Figure 2. Spread of Phytophthora cryptogea **on** Gervera jamesonii **in rockwool culture by recirculating nutrient solution.**

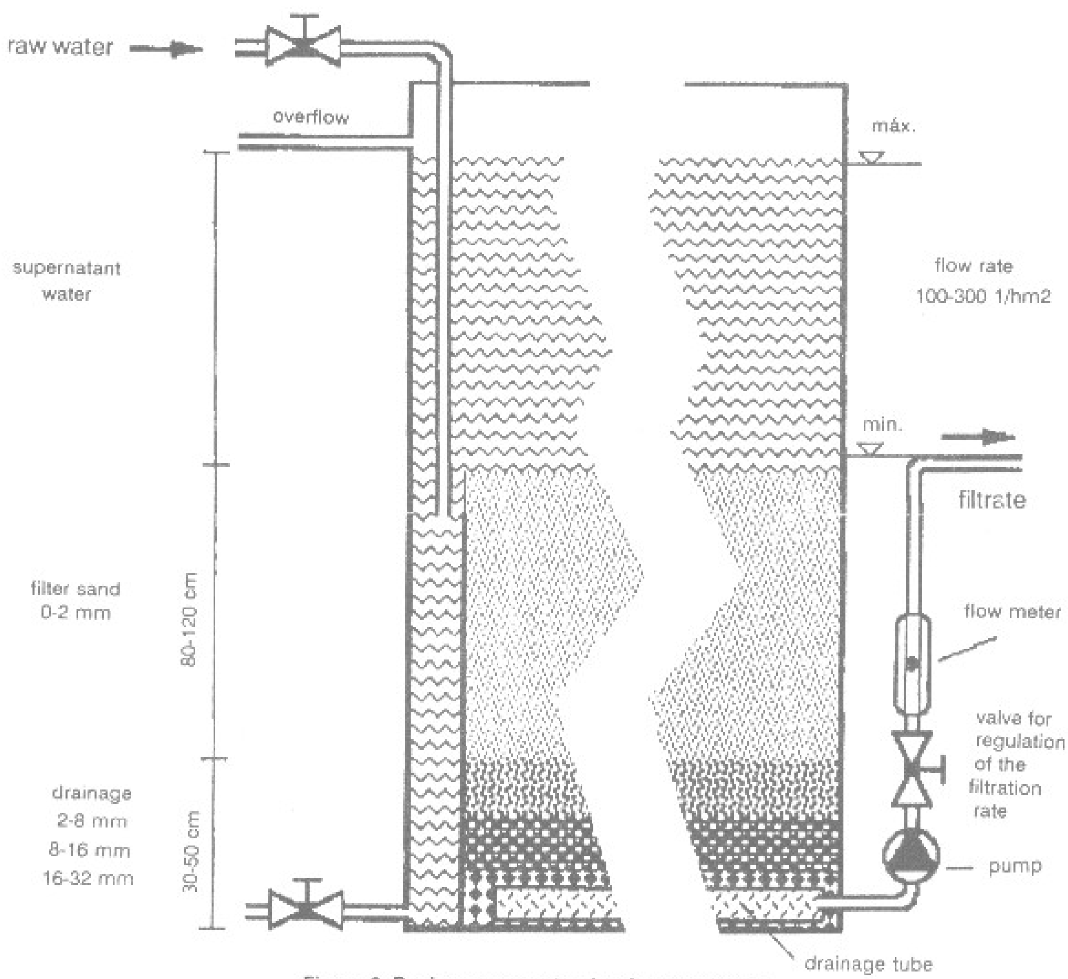

Figure 3. Basic components of a slow sand filter.

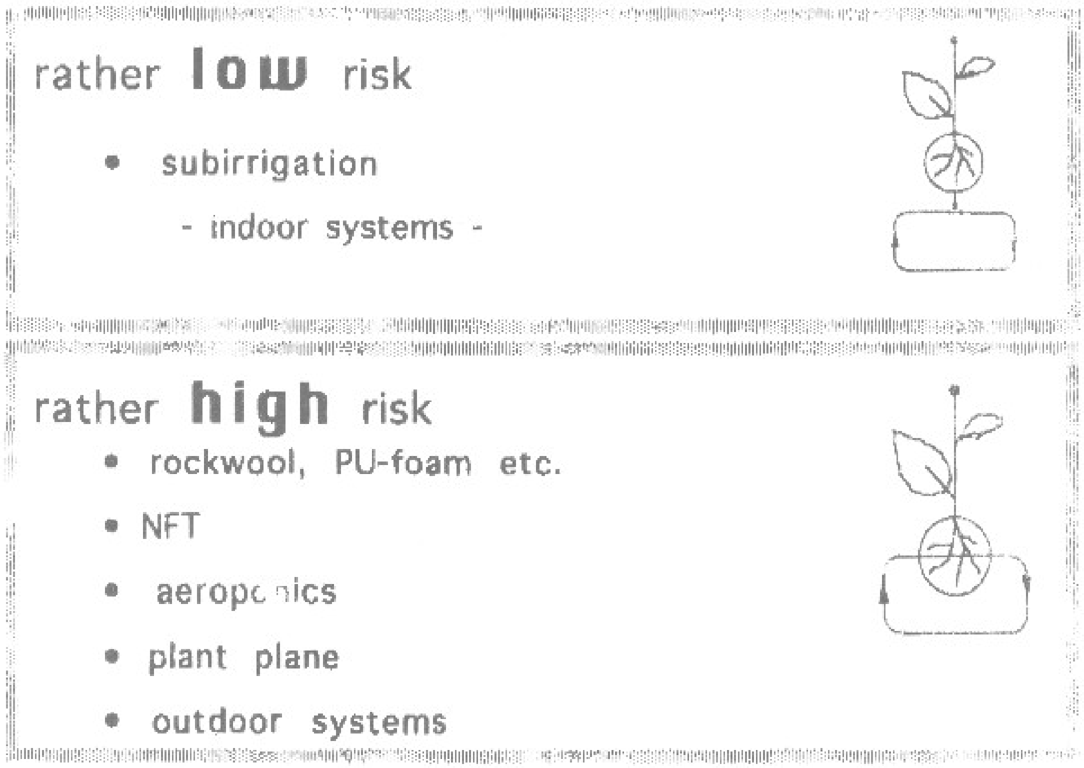

Figure 4. Risks of spreading diseases of closed irrigation systems.

especially (e.g. metalaxyl) can be added with good success. In these cases the amount of fungicide required per plant or cultivation area should be calculated on the basis of the usual drench application.

CONCLUSION

The risk of disease dispersal depends to a high degree on the type of recirculating system (see Figure 4). The most important factor is whether or not the surplus water has passed through the root system. Therefore indoor subirrigation systems pose a rather low risk for spreading diseases by the recirculating nutrient solution.

However, recirculating irrigation systems often utilised in the production of cut flowers, stock plants or vegetables generally pose a considerable risk of spreading root pathogens because the nutrient solution, having passed the root system of possibly diseased plants, might be contaminated with pathogens. In this case the reuse of surplus water can result in a rapid spread of disease. Therefore, before being reused, drainwater of such systems should be disinfected.

In the Netherlands heating, ozonisation and to a lesser extent UV- irradiation are the most common disinfection methods. They usually require a high investment of more than DM 50,000 and heating has a high energy consumption. For an economical application of such techniques, large cultivation areas of more than 1 ha are required, and these are not common in Germany. The results of several studies at the Research Station Geisenheim (Germany) indicate that the efficacy of slow sand filtration against phytopathogens including fungi, bacteria and even viruses is acceptable under practical conditions. It is a simple low-cost technique which can be easily adapted to any size of cultivation area and can be constructed by the grower himself.

In contrast to other European countries, the registration of pesticides in Germany does not usually cover the application to the nutrient solution of closed irrigation systems. General recommendations are not possible. With hydroponic systems the concentrations can and must be drastically lowered in comparison to the usual application to buffered media like soil or peat. With subirrigation of pot plants the amount of pesticide required per plant or cultivation area should be calculated on the basis of the usual drench application.

REFERENCES

BOWE, R.; REINELT, J. (1991). Edelnelken in NFT-Kultur Deutscher Gartenbau, 46 (3), 138-40.

DAVIES, J.M.L. (1981). Alternative wilt controls Grower. Jan. 15, 19-21.

DEKKER, A.; W.TH. RUNIA. (1991). Gedrag oxamyl bij recirculatie en vrije drainage: Bij recirculeren geeft minder middel hetzelfde effect Vakblad voor de Bloemisterij, 46 (31), 30-31.

ELSNER, B. (1988). Bekämpfung von Pythium spp. an Pelargonium- Zonale. Mutterpflanzen in NFT-Kultur. Nachrichtenblatt für den Pflanzenschutz in der DDR, 42 (12), 242-244.

FRIEDEL, S.; W. WOHANKA; H.-D. MOLITOR. (1991). Erica: Phytophthora in FlieBrinnen bekämpfen Gärtnerbörse und Gartenwelt, 91 (2), 69- 72.

JAMART, G.; G. DE PREST; O. KAMOEN. (1988). Control of Pythium spp. on ornamental plants in a nutrient-film system. Med. Fac. Landbouww. Rikjksuniv. Gent 53 (2b), 625-634.

KREBS, E.-K. (1985). Erst bei hoher Sporendichte birgt Fusarium Gefahr Gärtnerbörse und Gartenwelt, 85 (48), 1791-1793.

MOLITOR, H.-D.; W. WOHANKA. (1992). Recirculating irrigation systems: A European perspective Proc. 8th Conf. on Insect and Disease Management on Ornamentals, Orlando-Florida, USA, 103-118.

OBIEGLO, U.; B. KREBS; H. JUNGE. (1990). Einsatz mikrobieller Antagonisten gegen die Fusarium-Welke der Edelnelke (Fusarium oxysporum f.sp. dianthi) in hydroponischen Kulturverfahren. Nachrichtenblatt für den Pflanzenschutz in der DDR, 44 (8), 169- 171.

PRICE, D.; A. DICKINSON. (1980). Fungicides and the nutrient film technique. Acta Horticulturae, 98, 277-282.

PRICE, T.V.; M.K. MAXWELL. (1980). Studies of disease problems and their control in hydroponics in Australia. Acta Horticulturae, 98, 307-315.

RATTINK, H. (1983). Spread and control of Fusarium wilt in carnations on artificial substrates. Acta Horticulturae, 98, 307- 315.

-----. (1990). Epidemiology of Fusarium wilt in ebb and flow system. Netherlands Journal of Plant Pathology, 96, 171-177.

------; M.C. DIL; M.M. VERSCHOOR. (1989). Verspreiding verwelkingsziekte bij Cyclamen op ebvloedsysteem nihil. Vakblad voor de Bloemisterij, 44, 60-61.

RUNIA, W.T. (1991). Betrouwbare ontsmetting (drain) water Vakblad voor de Bloemisterij, 46 (3), 20-22.

-----; J. NIENHUIS. (1992). Twee ontsmetting- systemen werken niet goed Vakblad voor de Bloemisterij, 47 (5), 99.

SANOGO, S.; G.W. MOORMAN. (1990). Behaviour of Pythium sp. in flood and drain subirrigation system. Phytopathology, 80 (1), 123.

VAN PEER, R.; T. XU; H. RATTINK; B. SCHIPPERS. (1988). Biological control of carnation wilt caused by Fusarium oxysporum f.sp. dianthi in hydroponic systems. ISOSC Proceedings, 361-371.

WOHANKA, W. (1985). Kultur in Bewässerungsrinnen ohne erhöhtes Krankheitsrisiko zierpflanzenbau mit internationaler gartenbautechnik, 25 (26), 1088-1089.

WOHANKA, W. (1988). Spreading of three phytopathogenic fungi in rockwool culture of poinsettia stock plants. Acta Horticulturae, no. 226, 707-709.

WOHANKA, W. (1993). Die Langsamfiltration - eine preiswerte Alternative zur Wasserdesinfektion. Gartenbauwirtschaft, no. 10, 4-8.