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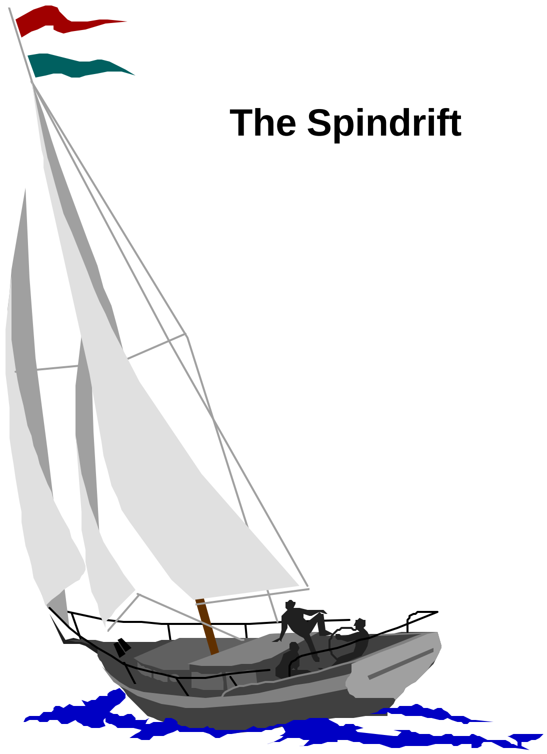

Ralph Freeman retires

A man noted for his nautical skills as well as his floriculture zeal has retired.

After 36 years on the faculty of Cornell's Cooperative Extension Floriculture Faculty, Floriculture Agent Ralph Freeman, recently retired. Ralph served at the Suffolk county office in Riverhead, Long Island, New York and was an avid supporter of the floriculture industry on Long Island. Ralph was a real friend to the Rutgers Extension program and for many years appeared on our Greenhouse Engineering and Environment Control Short Course Program held each January in New Brunswick.

Ralph was long-time Floriculture editor of Horticulture News, a publication of Cornell Cooperative Extension. This monthly publication is designed to give practical information to the Horticulture community on Long Island and around the world. Ralph is also a regular columnist in GM*Pro*, an international trade magazine,

Cornell's Research Greenhouse complex at Riverhead will also feel Ralph's retirement. Ralph spent many hours doing applied research for the industry and then extending that information to the growers through meetings, personal visits and the newsletter as well as personal contact via the telephone.

Ralph is nationally and internationally known for his expertise in floriculture. He is a frequent lecturer/teacher on state, national and international educational and scientific programs for producers and marketers of floricultural crops and an author of hundreds of publications. He often serves as an unbiased mediator in family business disputes and problems and is a frequent counselor to new business ventures.

Ralph participates in and is a member of the American Society for Horticulture Science; Society of American Florists; International Plant Propagators Society; Ohio Florists Association; Bedding Plants, Inc.; Roses, Inc.; Perennial Plant Association; and an advisor to New York State Flower Industries, Inc., and Long Island Flower Growers.

Ralph and his lovely wife Carol, a registered nurse, have 3 children, two daughters and a son. Ralph is a man of faith and active in the Eastport Bible Church and the Gideons International, an association of Christian business and professional men.

It has been a privilege for me to know and work with Ralph for so many years. He is a true friend and we welcome him into the select retiree's division of our industry.

Cornell University is searching for new person to fill Ralph's nautical and floriculture shoes. One of the requirements of course is that he or she must be an avid sailor!

Bill Roberts, Professor Emeritus

Life of Polyethylene Glazing Film

The life of polyethylene greenhouse glazing film can be adversely affected by chemical exposure to certain chemicals commonly used in greenhouse production. The time and method of application of the pesticide affect this phenomenon. Although foggers and aerosol bombs give much better coverage, they tend to coat the glazing film to a greater degree than sprayers which apply the chemicals directly to the plant material.

You should avoid contact between the glazing film and chemicals containing bromine, chlorine, fluorine, iodine, sulfur, petroleum and copper wood preservatives. The chemicals listed below are known or suspected to prematurely degrade polyethylene greenhouse film, especially those treated with an anti- condensate additive or an IR heat reducing additive. The presence of these chemicals can also effect the overall performance of the film. The list includes:

Banrot
Chloropicrin
Chlorine gas
Chlorpyrifos Dursban, Lorsban, etc.
Dithiocarbamates: Manzate, Maneg
Penncozeb, Dithane, Polyram etc.
Fluvalinate: Mavrik
Vinclozolin: Roilan, Ornalin
Dienochlor: Pentac
Chlorthalonil: Bravo
Pentachloronitrovenzene: Terrachlor
Oxamyl: Vydate
Chloride
Methyl Bromide
Bromine gas
Sulfur
Permethrin and other syn. Pyrethroids
Captan
Diazinon
Manozeb: Penncozeb, Dithane Manzate
Copper Hydroxides: Phyton 27 Kocide,
Copper sulfate
Chlorine bleach
Bromoxynil: Buctril
Silver Thiosufate
Methomyl: Lannate.

Inflation with inside or outside air?

The primary reason for using outside air for inflation is to reduce the potential for condensation between the two layers of film. Condensation can reduce light (PAR) transmission and encourage algae growth. If the warm and moist greenhouse air is used for inflation of the two layers of film, it will be cooled resulting in condensation of the moisture in the air. Outside air used for inflation will always be warmed, preventing condensation from occurring. A second reason for not using inside air for inflation is the potential for incorporation of the various chemicals mentioned in the previous column into the plastic envelope. It has been observed that degradation and failure of the film from chemical activity within the greenhouse production system is increased at the point of entry of the air into the envelope when it is drawn from the inside. Using outside air for inflation further reduces the risk of shortened film life by eliminating the potential for chemical activity on the film.

The degradation of two different polyethylene greenhouse films was documented in a paper in the recent proceedings of the 15th International Congress for Plastics in Agriculture, held Sept 23-27, 2000 at Hershey, PA. The paper was titled “Effect of Pesticides on the Degradation of EVA Plastic Films for Greenhouse Covering” The authors indicate that light transmittance was significantly reduced in as short a period as 16 weeks because of the presence of copper, sulfur and chlorine containing pesticides. Slight variations were observed in the mechanical properties after 16 weeks of weathering.

More info at http://www.plasticulture.org

We are indebted to Steve Bogash, Commercial Horticulture Agent, Penn State University Cooperative Extension and Tyco Plastics, manufacturer of Tufflite greenhouse glazings for this information on chemical effects on plastic.

ETHICS ARE PRACTICAL

This article is a guest editorial by Bill Roberts and first appeared in Volume 13 No. 3 of the Hort Engineering Newsletter, 5/1998.

Each fall I used to teach a section in our senior design course for our undergraduate engineering students entitled ETHICS. Ethics comes from the Greek word, ***ethikos*** meaning, the science of moral duty, broady, the science of ideal human character and moral principles, quality or practice.

Ertas and Jones, in the book titled "Engineering Design Process" by Wiley, 1993 define ethics as follows: "The science or doctrine of the sources, principles, sanctions, and ideals of human conduct and character; the science of the morally right."

In the course I told the students that character always leads to conduct. I further state that ethics are ***caught*** more than ***taught***. Many people believe that a young person's ethical standards and outlook are established at a young age under the influence of family, church, friends and school teachers and that this outlook cannot be changed or significantly influenced at a young adult stage when entering university. However, others contend that ethics need to be applied to the college curriculum and students need to become aware of its importance.

Following is a quote from Peter Boer. **"Ethics have historically been linked to philosophy and religion — peripheral to the core academic interests of most engineers and scientists. Yet, it is not always recognized that ethical lapses have enormous economic consequences for employers and often tragic personal consequences fo the individual involved. In a real sense, ethics in a technological society are practical and ethics training has tangible value for corporations and businesses. A reputation for integrity is a business asset- and its opposite can literally become a liability."**

F. Peter Boer, Executive Vice President
W.R. Grace and Co.

Let your Editor know if you agree.

Energy Conservation and the Use of $C0_2$

Bill Roberts

Recently, I had the privilege of visiting Ivy Acres in Calverton. I was shown a new boiler used for heating a new greenhouse facility. It was designed to use natural gas so that CO_2 could be used for crop production. This is an interesting design problem because CO_2 is mostly used during the daytime when less heat is required.

I had encountered this dilemma while visiting Bonita Springs in Arizona. During a greenhouse tour I questioned our guide about the absence of a thermal screen. The guide stated they were using external white wash for shading. I then brought up the idea of energy conservation during the heating season. I indicated that from our experience they could expect a 30% reduction in energy with interior moving thermal screens. His response to me was that if they used the thermal screen at night they couldn't use all of the energy produced during the day by the boilers. When he said this, I finally realized their mode of operation.

During the day one of the boilers, operating on natural gas, runs full-time producing hot water, which is stored in five large storage tanks, and CO_2 to enhance the tomato production. The stored hot water is used at night to heat the greenhouse through the floor, perimeter, and overhead heating pipes. On mild nights, the use of a thermal screen would reduce the heating load. This, in turn, would result in less demand for hot water and thus less operating time for the boiler to produce CO_2 during the following day.

The thought occurred to me that perhaps another source for CO_2 could be found and the 30% reduction in heating costs resulting from the installation of the thermal screen could be used to pay for the system. Another solution would be to put the heat produced during the day into a floor heating system which could act as a larger thermal storage buffer with minimum impact on the air heating system. I hope that Ivy Acres will be able to try this approach in their new range.

Continuation of an article by Mr. Erik Van Os, which started in Vol. 16 No. 2, March, 2001.

If you evaluate the soilless growing systems used in Europe, you see most developments in crops grown at low plant densities (fruit vegetables) or in crops which allow an increase in space utilization (rose, strawberry). Economic factors are decisive. For a better environment you should not look at one aspect only (leaching of fertilizers) but at the overall situation of a business, such as energy, fertilizers, pesticides. Therefore, Dutch growers still have to complete a major task before 2010. A covenant, between growers' associations and the government, allows individual growers to follow their own way to achieve new legal targets between 2000 and 2010. In co-operation with a consultant each grower makes his/her own "Environmental Business Plan" in which he/she sets out how to achieve the 2010-goal for each nursery. Generally, there is an increased awareness about horticultural production in Europe, but legislation plays a more important role in north and west Europe compared to south and east Europe.

5. Disinfection methods

A number of disinfection methods proved successful over the last ten years (Anonymous, 1996), as discussed in the following overview.

5.1 Heat treatment

Heat treatment is the most frequently used method. IMAG made this method technically suitable for treatment of recirculating nutrient solutions, after which the research station in Naaldwijk tested the method for elimination of pathogens (Runia *et al.*, 1988). The excess nutrient solution returns from the plants and is collected in a recatchment tank. From this tank the solution is pumped into a heat exchanger, where it is preheated to a temperature of about 80°C by heat recovery from already disinfected water. In a second heat exchanger the solution is heated to the disinfection temperature, using an external heat source. The disinfected solution flows back to the first heat exchanger to be cooled down and subsequently it is stored in a so-called "clean water tank". There is much discussion about the disinfection temperature. In the first trials a 100% killing of different pathogens was achieved at 95°C at an exposure time of 10 s. For security reasons an exposure time of 30 s is recommended. Then, all organisms are killed. Later, Runia (1998) proved that similar results could be obtained by decreasing the disinfection temperature and increasing the exposure time: 90°C and 2 minutes, 85°C and 3 minutes for a complete disinfection (elimination of all pathogens including viruses) and 60°C for 2 minutes for a selective disinfection (only elimination of fungi, bacteria and nematodes) (Runia & Amsing, 2000). The big advantage of the latter disinfection temperatures is that no extra, external, heater is needed, which makes the unit cheaper. The amount of gas needed to heat the water (1 m^3 gas per m^3 water) is a disadvantage, but it is reduced to 0.6 m^3 gas per m^3 water in the latter case with using temperatures for a longer duration.

5.2 Ozone treatment

Ozone (O_3) is a very powerful oxidizer and reacts with all living organic matter, but also with chelated iron. It can kill all organisms in the water, depending on exposure time and concentration. The water has to be prefiltered to reduce the organic load and the pH has to be lowered to increase the stability of the ozone. In all installations the drain water is treated in batches (1 or 2 m^3) in a closed tank. From several trials Runia (1996) concluded that an ozone supply of 10 g per hour per m^3 water with an exposure time of one hour is sufficient to kill all pathogens. The system is expensive and many pre-treatments and precautions have to be made. Therefore, ozone treatment is not very popular anymore although technically it works well.

5.3 Ultra-violet radiation (UV)

Only recently, UV is becoming popular. In the eighties organic material in the water caused unreliable results and the investment was high. Now the system is comparable with heat treatment and much cheaper than ozone. UV is an electromagnetic radiation with wavelengths between 200 and 280 nm (UV-C). The optimum wavelength of 254 nm has a strong killing effect on micro-organisms. Both, high and low pressure lamps may have the same performance in eliminating pathogens, but in general the high-pressure lamp is less energy efficient. The recommended dose varies from 100 mJ/cm^2 for eliminating bacteria and fungi to 250 mJ/cm^2 for eliminating viruses (Runia, 1996). These values are only valid when the transmittance of the water is sufficient (realised by an extra rapid sand filter), otherwise too many debris particles provide some shade for the pathogens and a chance to survive. It is also possible to increase the transmittance of the drain water by mixing it with supply water. Less filtering is needed, but the disinfection capacity decreases and, consequently, the investment increases.

5.4 Membrane and slow sand filtration

Membrane filtration can be divided into reverse osmosis, hyper-, nano-, ultra- and microfiltration, depending on the size of the membrane. Reverse osmosis is able to remove all ions from a solution. It is sometimes used as a source for supply water in addition to rainwater. Membranes for ultra- and microfiltration are not much in use for removing pathogens. The first generation membranes were very expensive, while the reliability was too low. Clogging and leaking were common failures. The present generation of membranes is more reliable and cheaper, but getting rid of the brine (the water with accumulated salts) is an increasing problem, while the investment is still rather high.

For about 5 years it is possible to buy a slow sand filtration installation (Wohanka, 1995; Van Os *et al.*, 1997b; Runia *et al.*, 1997). *Phytophthora* and *Pythium* can be eliminated completely by this method, but fusarium, viruses and nematodes only partly (90-99.9%). The principle is based upon a supernatant water layer which trickles slowly through a sand layer. IMAG experiments proved that a flow rate of 100 L/m^2/h increases the performance just like the selection of finer sand (0.15-0.35 mm; D_{10}< 0.4 mm). Satisfactory performances can also be obtained when either the grain size increases to 1 or 2 mm or the filtration rate increases to 300 L/m^2/h (Wohanka *et al.*, 1999). Installations were already in use before much was known on the limiting conditions and the working mechanism. Now, the installations are improved, based on the results of the experiments mentioned. This method may be of great interest, as the investment is much lower compared to heat treatment and UV. However, it is known that nematodes pass the filter and may infect roots of healthy plants (Van Os *et al.*, 1997).

6. Role of the microflora

In the last five years a change in the way of thinking about disinfection has been noticed. Before that time, all methods were based on eliminating all pathogens and sterilising the nutrient solution (heat treatment, ozone, UV). Now you can see a different approach. It was already known that a soilless system is not a sterile system (Berkelmann, 1994). Until recently it was unknown which role the present microflora plays. Therefore, it is perhaps not adventageous to kill all life in the solution; there is a certain microflora present which plays its role in suppressing diseases (McPherson *et al.*, 1995; Postma, 1996, Postma *et al.,* 1999 and 2000, Tu *et al.*, 1999). For example, *Pythium* can disperse very rapidly in a sterilised environment, while its growth in a non-sterilised environment is much slower. Similar phenomena can be seen with certain *Phytophthora* species. The conclusion is that certain micro-organisms are able to suppress diseases. If they are killed, the nutrient solution looses its suppressiveness and a fast outbreak of a disease can be the result. However, these claims are not completely proven. Slow sand filtration is a method in which the microflora present is not entirely killed, but only part of the micro-organisms are eliminated. Therefore, this method can play an important role in suppression of diseases by micro-organisms (Postma *et al.*, 1999).

Research, funded by the European Union, just started to validate these claims. The essence of the research project (MIOPRODIS) will be a comparison between active disinfection (sterilisation of the nutrient solution by a UV treatment), passive disinfection (slow sand filtration treatment) and a control without any disinfection. It is the goal to determine the dynamics of the microflora and the metabolites in these three systems growing tomato, cucumber or gerbera, while a part of the plants are infected with *Pythium aphanidermatum* or *Phytophthora cryptogea*. The outcome should be a sustainable growing system which is particularly interesting for small scale nurseries. First results indicate that plate counts after membrane filtration is most suitable to be used for detection of the pathogens in following trials. Nested PCR may be additionally used for detection of very low numbers of spores, i.e., after slow filtration or a UV-treatment. A serological method proved its sensitivity for *P. cryptogea*. In slow filters, fine sand is not the only medium that works, glass wool, rockwool and coarser sand types can be used as well.

7. Metabolites

The pressure to introduce closed growing systems also stimulated discussion about the presence of metabolites released by plant roots and/or micro-organisms in the recirculating solution and their usefulness and/or non-usefulness (Waechter-Kristensen *et al.*, 1994 and 1999). Preliminary knowledge about this has been collected from growing systems without any disinfection. A relationship has to be established between the quantity of metabolites in the solution and the effect on them of an active disinfection treatment such as sterilization (heat treatment or UV-radiation) or with a passive, non-sterilising treatment (slow (sand) filtration).

Another relation unknown relationship is the one between the substrate in which the plants are grown and the quantity of metabolites in the solution. Substrates can be distinguished into liquid hydroponics in which no solid substrate is used except for rooting and sowing (nutrient film technique (NFT), aeroponics, deep flow technique), and inert inorganic substrates such as mineral wool, polyurethane foam or perlite and organic substrates such as peat, coir or wood fibres. The expectations are that in each of the substrates the microbial balance as well as the accumulation of metabolites is different. In the already mentioned project MIOPRODIS, samples are being analysed of a NFT crop and of a rockwool crop. Preliminary results on tomato seedlings show that addition of different concentrations of 10 compounds affect emergence and germination negatively above a concentration of 100 µM (Jung & Waechter-Alsanius, 1999). The next questions are whether those compounds achieve such concentrations in a full grown crop and whether they have a negative effect on growth. Similar to the microflora, first the metabolites are being analysed in a steady situation, after which the dynamics during cropping will be the subject of research.

8. Conclusions

In Europe, more than 11,000 ha of hydroponic growing systems are in use, growing mainly fruit vegetables, rose, and gerbera. In the Netherlands, no further increase is expected, but in other European countries soilless systems will increase rapidly with another 10,000 ha expected in the coming years. The ban on the use of methyl bromide and, in its tracks, other soil fumigants will stimulate the change to closed hydroponic growing methods in greenhouses.

Most growing systems in use are cheap; economics are still of greater importance than environmental concerns. Such systems for fruit vegetables consists of either enveloped rockwool slabs or bags with perlite or pumice, lying in a plastic foil, polypropylene trough or a PVC drain profile. Suspended troughs may be a solution for capital intensive nurseries.

Heat treatment and UV are the most popular disinfection methods in the Netherlands. The recirculating nutrient solution is sterilized, the investment is rather high and, consequently, not applicable for small nurseries (less than 1 ha). Slow sand filtration can partly eliminate pathogens, but keeps the present microflora alive. Therefore, it can be a method for controlling the nutrient solution in a more sustainable way. Furthermore, it is a cheap method and suitable in southern Europe where the level of investment is much lower. Recently, research on the role of the microflora in the nutrient solution was started. Preliminary results show a shift in the population of the resident microflora in the nutrient solution during cropping as a result of the disinfection method. This may give us another look at the importance of the present microflora to suppress soil-borne pathogens.

9. Acknowledgements

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10. References (Partial List). A complete list is available from the author.

Berkelmann, B., W. Wohanka, G.A. Wolf, 1994. Characterisation of the bacterial flora in circulating nutrient solutions of a hydroponic system with rockwool. Acta Horticulturae 361, pp. 372-381.

Braun, A.D., and D.M. Supkoff, 1994. Options to methyl-bromide for the control of soil-borne diseases and pests in California with reference to the Netherlands. Internet: http//www.cdpr.ca.gov/docs/dprdocs/empm/soilsol.htm, 18 p.

McPherson, G.M., M.R. Harriman and D. Pattison, 1995. The potential for spread of root diseases in recirculating hydroponic systems and their control with disinfection. Mededelingen van de Faculteit Landbouwwetenschappen Universiteit Gent, 60/2b, pp. 371-379.

Postma, J., 1996. Mechanisms of disease suppression in soilless cultures. IOBC/WPRS Bulletin 19(6), pp. 85-94.

Postma, J., E.A. van Os, G. Kritzman, 1999. Prevention of root diseases in closed soilless growing systems by microbial optimization. Mededeling Faculteit Landbouwwetenschappen Univ. Gent 64/3b, pp. 431-440.

Postma, J. M.J.E.I.M. Willemsen-de Klein and J.D. van Elsas, 2000. Effect of the indigenous microflora on the development of root and crown rot caused by *Pythium aphanidermatum* in cucumber grown on rockwool. Phytopathology, Vol. 90, No. 2, pp. 125-133.

Ruijs, M.N.A., and E.A. van Os, 1991. Economic evaluation of business systems with a lower degree of environmental pollution. Acta Horticulturae 295, pp 79-84.

Ruijs, M.N.A., 1994. Economic evaluation of closed production systems in glasshouse horticulture. *Acta Horticulturae* 340, p 87-94.

Runia, W.Th., E.A, van Os and G.J. Bollen. 1988. Disinfection of drainwater from soilless cultures by heat treatment. Neth. Journal of Agricultural Science, nr 36, pp231-238.

Runia, W., 1996. Disinfection of recirculation water from closed production systems. In: *Proceedings of the Seminar on closed production systems*, E.A. van Os (ed.), IMAG-DLO report 96-01, p 20-24.

Runia, W.Th., J.M.G.P. Michielsen, A.J. van Kuik and E. A. van Os, 1997. Elimination of root infecting pathogens in recirculation water by slow sand filtration. Proceedings 9th Int. Congress on soilless cultures, Jersey, pp. 395-408.

Tu, J.C., Papadopoulos, A.P., Hao, X. and Zheng, J., 1999. The relationship of a pythium root rot and rhizosphere microorganisms in a closed circulating and an open system in rockwool culture of tomato. Acta Horticulturae 481, 577-583.

Van Os, E.A, 1994. Closed growing systems for more efficient and environmental friendly production. Acta Horticulturae 361, pp. 194-200.

Van Os, E.A., M.A. Bruins, J. Van Buuren, D.J. van der Veer and H. Willers, 1997a. Physical and chemical measurements in slow sand filters to disinfect recirculating nutrient solutions. Proceedings 9th Int. Congress on Soilless Culture, Jersey, pp. 313-328.

Van Os, E.A., J.J. Amsing, A.J. van Kuik, H. Willers, 1997b. Slow sand filtration: a method for the elimination of pathogens from a recirculating nutrient solution. Proceedings 18th Annual Conference Hydroponic Society of America, Windsor, Ontario, Canada, pp. 169-180

Van Os, E.A., 1998. Closed soilless growing systems in the Netherlands: the finishing touch. Acta Horticulturae 458, pp 279-291.

Van Os, E.A. and F. Benoit, 1999. State of the art of Dutch and Belgian greenhouse horticulture and hydroponics. Acta Horticulturae 481, pp765-767.

Van Os, E.A., 1999. Closed soilless growing systems: a sustainable solution for Dutch greenhouse horticulture. Water Sc & Tech, Vol. 39, No 5, pp 105-112.

Waechter-Kristensen, B., U.E. Gertsson and P. Sundin, 1994. Prospects for microbial stabilisation in the hydroponic culture of tomato using circulating nutrient solution. Acta Horticulturae 361, pp. 382-387.

Waechter-Kristensen, B., S. Caspersen, S. Adalsteinsson, P. Sundin and P. Jensén, 1999. Organic compounds and micro-organisms in closed hydroponic culture: occurrence and effects on plant growth and mineral nutrition. Acta Horticulturae 481, pp. 197-204.

Wohanka, W., 1995. Disinfection of recirculating nutrient solutions by slow sand filtration. Acta Horticulturae 382, pp. 246-255.

Wohanka, W., H. Lüdtke, H. Ahlers, M. Lübke, 1999. Optimization of slow filtration as a means for disinfecting nutrient solutions. Acta Horticulturae 481, pp. 539-544.

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