Horticultural Engineering

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My first year on the job

It has been a little over a year since I started my assistant extension position at Rutgers University. As discussed in an earlier newsletter (Vol. 15, No. 3-4), our Bioresource Engineering department went through a significant change and it is now part of the Plant Science Department. We are actively recruiting for new assistant professor in Horticultural Engineering (instrumentation, sensing, and imaging). We hope to have this third faculty member come aboard some time this summer/early fall. Three faculty members will still not be enough to teach an entire four-year undergraduate program in Horticultural Engineering, but we hope to attract additional faculty in the coming years.

It has been a pleasure working with many excellent colleagues, both extension specialists and agents. We have an extensive and dedicated network of people sincerely interested in helping and supporting our growers. Our greenhouse industry is very diverse and I believe this diversity is a strong asset. It allows us to learn from each other and keeps us informed about "what else" is going on in the industry. More than ever, our industry is faced with continuous change and it is always a good idea to be well informed about opportunities.

For many growers, one of the biggest challenges this last year has been dealing with the rising fuel prices. Unfortunately, it doesn't appear this problem will be going away any time soon. In fact, many energy savings strategies studied shortly after the last energy crisis in the seventies are being reevaluated (e.g., alternative fuels, high efficiency heaters, energy curtains, etc.). Another area of concern is labor. Many growers have commented how difficult it is to find and retain good labor. Our colleges and universities, including Rutgers University, have few programs to train high quality and well rounded greenhouse growers. This is somewhat surprising given the fact that top salaries are available for individuals with these kinds of skills. Some growers are looking at automation as a way to cut labor requirements, others are relying on (mostly) foreign labor. As with the high energy prices, the shortage of qualified labor is not likely to be resolved soon.

In summary, I had a lot of fun getting to know many people in the industry as well as in the extension service. It is a challenge to keep up with all the different developments, but I hope I will be able to continue to contribute to the greenhouse industry in New Jersey. As always, I am looking forward to your input and suggestions.

ACESYS IV International Conference

Nearly 300 people attended this International conference dealing with Automation, Culture and Environment as they interact in a System in Controlled Environment Agriculture production systems. Starting on page two is the first part of an article by one of the participants, Mr. Erik Van Os from the Netherlands. The article deals with methods used to meet the challenge of disease control in contained growing systems which are required by law in the Netherlands. Many US growers are using these systems to control runoff and this article contains helpful information for them.

Annual Greenhouse Design Short Course

The annual Greenhouse Design and Environmental Control short course held on January 8 and 9 was very successful based on the evaluation forms completed as part of the course. Approximately 20 people, representing many different areas of the greenhouse business attended. The highlight of the course, as usual, was the tour. This year's visits included the research open-roof greenhouse on campus, the Burlington County Resource Recovery Research Greenhouse, and Kube Pak Corporation in Allentown, NJ.

ACESYS IV International Conference

Paper review.

The following is a condensed version of a paper presented by Mr. Erik Van Os at the 4th ACESYS Symposium. Single copies of the complete paper are available from the author.

NEW DEVELOPMENTS IN RECIRCULATION SYSTEMS AND DISINFECTION METHODS FOR GREENHOUSE CROPS

E.A. van Os

IMAG, P.O. Box 43, 6700 AA Wageningen, The Netherlands;

E-mail: e.a.vanos@imag.wag-ur.nl

Key words: hydroponics, substrate, UV, ozone, heat treatment, methyl bromide, tomato, cucumber, rose, microflora, metabolites

Abstract

Since the early eighties hydroponic or soilless growing systems are in use for the cultivation of greenhouse crops. Mostly, vegetables (tomato, cucumber, pepper), gerbera and rose crops, with only a few plants per m^2, changed to hydroponic systems. In the Netherlands the area stabilized around 5,000 ha. In the rest of Europe there is an estimated area of 6,000 ha, but a further increase of 10,000 ha can be expected in the coming years. Especially in Spain a rapid change to hydroponics may be expected, stimulated by the ban of the soil fumigant methyl bromide. The commercial systems in use are as cheap as possible, mostly with single use materials (substrate, plastics). Sometimes more sustainable systems are in use.

Heat treatment and UV are most popular disinfection methods in closed hydroponic systems. Slow sand filtration may become a good alternative, especially as more research is able to confirm the ability of the resident microflora to suppress soil-borne pathogens such as *Pythium* and *Phytophthora*.

1. Introduction

In this article an overview will be given of the developments in hydroponic growing systems, disinfection methods, and related new developments in the European greenhouse industry. Soil-borne diseases have always been a problem in the greenhouse industry. In Europe, soil-borne diseases are destroyed by fumigants or by steaming when production occurs in soil. In many countries the soil fumigant methyl bromide is still in use to control soil-borne diseases in greenhouses and outdoor vegetable production. Methyl bromide is extremely toxic and harmful to the environment. European regulations ask to reduce the use of methyl bromide with 25% (based on 1991 use) before 1998 and with 50% before the end of 2005. Additionally, in the industrialised countries, under the Montreal Protocol, methyl bromide will be phased out by 2005 (total ban), because of its ozone depleting effects (Braun and Supkoff, 1994).

One of the alternatives for the use of methyl bromide is hydroponics or soilless growing. Currently, artificial substrates are used for tomatoes, strawberries, cucumbers, peppers, eggplants, and some flower crops, such as roses, gerbera, and orchids. In the Netherlands the use of methyl bromide has been reduced to zero, because of the changeover to soilless growing systems and legislation banning its application which was introduced simultaneously since the early eighties. Initially, hydroponic growing systems have been developed to get higher yields and a better quality. As an added benefit they were found to eliminate emissions of water, fertilizers and pesticides to the environment.

Nowadays, hydroponic growing systems are common in horticulture in most of the European countries, although not in each country on a large scale. Advantages of hydroponic systems compared to soil grown crops are:

- growth and yield are independent of the soil type of the cultivated area;
- better control of growth by use of improved water quality and better fertigation;
- increased quality of products by improved growth control;
- pathogen-free start by use of substrates other than soil and/or easier control of soil-borne pathogens.

Of course, there are a number of disadvantages such as the demand for high water quality, high investments, and higher costs for fertilizers. In most cases open or run-to-waste systems rather than “closed” or recirculation systems are adopted. In such open systems superfluous nutrient solution freely leaches to ground and surface water. These days, based on economic motives and environmental concerns, soilless systems have to be as closed as possible, i.e., with recirculation of the nutrient solution, reuse of the substrate, and use of more sustainable materials. The advantages of closed systems compared to open systems are a reduction of the amount of waste material, less pollution of ground and surface water, a more efficient use of water and fertilizers and lower costs because of the savings. Closed soilless systems potentially have a few significant disadvantages. Apart from the demand for high quality supply water, there is a risk of rapid dispersal of soil-borne pathogens by the recirculating nutrient solution and accumulation of potential phytotoxic metabolites and organic substances in the recirculating nutrient solution. Where such systems have been adapted commercially, growers attempt to overcome the problems of pathogen dissemination by disinfecting the water by heat or ozone treatment and UV-radiation (sterilization or active disinfection). Such treatments need a high investment but functioned as an insurance: to avoid outbreaks of a root disease and loss of yield, you have to pay for the equipment. In the last few years researchers became aware that the resident microflora may play a certain role in suppressing diseases and, consequently, the nutrient solution should not be sterilized. Preference should be given to passive disinfection methods which eliminate pathogens and keeps the resident microflora alive. Slow sand filtration is such a treatment, besides, it is a robust and cheap method. Research has to be conducted to validate this preference and to proof its commercial value and will it be partially reported here.

2. Area of protected cultivation and hydroponic growing systems

In Table 1 an overview is given of the area of protected cultivation and the area of open and closed hydroponic growing systems in several countries in Europe (Van Os & Benoit, 1999). The figures should be seen as an indication. Sometimes the collection of data is not very precise, sometimes the definitions are different and sometimes the figures are already rather obsolete in comparison to the rapid changes.

During the last five years the total area of protected cultivation is very stable as is the division between vegetables, flowers and pot plants in the Netherlands. Now, all fruit vegetables (tomato, cucumber, sweet pepper, eggplant) changed to soilless cultures (3,000 ha) and are required by law to use closed systems. The other (leaf) vegetable crops (e.g., radish and lettuce) are still grown in soil (joint area of 1,000 ha). Some flower crops (rose, gerbera, anthurium, orchid; together 1,000 ha) and pot plants (another 1,000 ha) are grown in soilless systems. Similar crop developments can be seen in other European countries and are to be expected in the coming years. In Spain developments are going very rapidly. Vegetables are very important, especially tomato, melon, sweet pepper and cucumber in the Almería region in the south-east of Spain, while floriculture is hardly present. There, an area of 30,000 ha of mainly plastic houses supplies the European market with vegetables. In Italy and Greece expansion of soilless growing methods is slower. In Germany, the north of France, UK, and Belgium fruit vegetables are mainly grown in (open) hydroponic systems.

In north-west Europe the estimate of the increase of the area is based on strict regulations in which environmental concern is the main issue. In the Mediterranean countries mainly economic reasons may lead to a change. For example, the availability of high quality water, the ban on methyl bromide, the investments needed, and expectations of yield and quality. Especially the area of fruit vegetables is of great importance, because for those crops closed hydroponic systems are the most economic.

3. Optimisation of growing systems

In the early eighties experiments started to develop soilless systems to get familiar with the way to grow the crops and to handle the system. Problems that had to be tackled were: the lay out of the growing system, the kind and size of the substrate, the root temperature, the composition, electrical conductivity and pH of the nutrient solution and the watering system. The surplus of water and fertilizers were simply flushed into the subsoil, being no problem until people got aware of the polluting effects of fertilizers on ground- and surface water. At that time all systems were open, there was only one closed growing system: nutrient film technique (NFT). In the Netherlands it never became very popular mainly because of the high growing risks (spreading of diseases, and the lack of buffer for making mistakes).

During the late eighties and early nineties many (closed) growing systems were developed. In the Netherlands it was said that horticulture should be safe, sustainable and competitive (National Environmental Policy Plan, 1989). At point a re-evaluation had to take place: which system is really sustainable, which crop or group of crops, and is it economical to invest in such a system (competitive). Studies (Lataster *et al.,*1993; Ruijs & Van Os, 1991; Van Os, 1994),

Table 1: Estimation of market prospects of closed soilless growing systems in several European countries for the coming 5 years.

Country	Area of protected cultivation (ha	Total area of soilless growing (ha)		Market prospects Expected area (ha) to change*	
		Open + closed systems (a)	Closed systems as % of (a)	Soil → soilless closed system	Open → soilless closed system
Netherlands	10,125	5,000	70	1,000	1,000
France	8,500	1,200	10	1,000	500
Spain	42,500	3,000	5	3,000	2,000
Italy	25,000	190	10	1,000	50
Germany	4,600	560	40	1,000	300
UK	1,000	460	50	100	100
Belgium	2,250	1,000	10	50	800
Greece	5,000	110	20	1,000	20

* explanation: Spain has now 3,000 ha soilless growing systems of which a 5% are closed systems. In the coming 5 years it may be expected that 3,000 ha will change from soil to soilless, while on 2,000 ha closed systems will be installed. This will result in 150 (5%) + 2,000 = 2,150 ha (35%) of closed systems.

investigating the economic (Ruijs, 1994), technical and environmental aspects of many (closed) soilless growing systems, proved that specific groups of crops can be distinguished, that these groups need a specific system, and that materials and substrates to be used are more or less sustainable. In a sustainable system materials and substrates should have low costs, have a life span of at least 3-4 years, have constant physical properties during use (steam-resistant), be safe (no damaging volatilization of gases) and be recycled by the supplier.

4. Present commercial application

Most of the system development have been taken place before 1994. Now, more than 6 years later, the results can be evaluated. Depending on the demands of the crop, the Dutch grower can select from about 6 materials and 10 substrates, all in many different variations, to come to a closed system. Each supplier offers many systems. Choosing is very difficult. Investment is mostly the decisive factor, but a low investment does not always give low annual costs or a sustainable system. Consequently, many systems are not completely sustainable, although they comply with legislation. They are installed, because they are cheap or they are easy to handle (Van Os, 1999).

For fruit vegetables multi-year rockwool or polyurethane foam slabs enveloped in polyethene foil lying in a profiled coated steel or polypropene trough is recommended to get a sustainable system. In north-west Europe, commercial firms mostly use single-year rockwool of several qualities (water content, density) and of several brands. Main reasons are the quick change of crops in winter and the clean restart. After the cultivation period all rockwool is collected and is recycled by the manufacturer. The area with polyurethane foam is decreasing, growers find the water content too low. The last few years coir is coming up, but experiences are variable. In the first years the quality was too variable (too much salt), but these problems are solved. It is also in use for its environmental friendly image: it is a natural product, it is a waste product of another industry, it can be composted after use.

In southern Europe there is more variety in the use of substrates. Especially perlite, delivered in bags, and locally mined pumice are used a lot. In these countries rockwool is used to a lesser extend because of its transportation costs. Instead of enveloped one-year-slabs, multi-year slabs can be laid in long shaped containers which stand in flat polypropene or coated steel troughs. The advantage is the sustainable use of container and slab for more than 5 years. Between two crops container and slab should be steam sterilised.

For collecting the drain water growers try to find the cheapest way. Not only sustainable troughs are used but also the so-called drain profiles of polypropene or poly vinyl chloride (PVC). Drain profiles are not self-supporting and are laid down partly into the soil, because they do not have a flat bottom. Preferably on top of the profile a slab in a container is placed, but mostly slabs enveloped in polyethene foil are used. Often you see a system where the trough is being made of foil in which a drain pipe is laid and upon which slabs or bags are placed. This system is also in use in the Mediterranean countries, it is the cheapest option, but not very sustainable. The foil has not a very long lifespan and must be renewed every year. Besides, the risk of leakages caused by sharp stones or mice is rather big. However, in the Mediterranean countries most of the systems are still open.

Another measure to make the system cheaper is the change from the traditional 4-row per 3.2 m system into a 2-row system at which the plants are trained in a V-shape, half of the materials are necessary, but the substrate slab is mostly bigger (20 cm in stead of 15 cm wide). In Spain the traditional lay-out in the greenhouse is already a V-shape trained crop with a row distance of 2 m.

For cut flowers to be harvested more than once, e.g. roses and carnations, similar systems and substrates as used in vegetable production are recommended. In some cases it is economic to use rolling benches to increase space utilization. Gerbera is grown on stages, because of labor efficiency. In that case only self-supporting troughs can be used. A coated steel trough in which long shaped containers with multi-year rockwool or polyurethane foam slabs are placed, is recommended. Another frequently used system is a trough in which containers can be placed in special devices. For crops growing span-wide with many plants per m^2, such as chrysanthemums, lettuce and radishes, it is recommended to plant in a polyethene foil filled with pumice stone, flugsand or sand as a substrate. In the Netherlands these crops are not grown hydroponically, mainly for economic reasons. In Belgium and Scandinavian countries there is an NFT-system for lettuce and herbs, at which the troughs can be spaced automatically. Technically a wonderful system, but economical there are doubts. Instead of a span-wide system a bed system with aisles consisting of polyethene foil and concrete or aluminium side supports filled with a loose substrate can be used for freesia, alstroemeria and amaryllis. Additional interest for the latter group of crops exists for production of bulbs or tubers. At this moment there are only some small scale experiments.

Another reason for the hesitation of growers to change to sustainable closed systems is the approval of a typically Dutch system: recirculation via the subsoil. In Dutch polders the groundwater level is at an artificial constant level of about 80 cm below ground level. Just above the ground water level there are drain pipes. Nearly all superfluous nutrient solution can be collected via the drain pipes and being reused. This system cannot be applied by all growers. There are two big risks resulting in limited application. First there is seepage: less drain water is available and nutrients pollute the environment. Secondly there is infiltration: bad quality water with salts and pathogens may enter your nursery. The big advantage of the system is the price: low investments (Van Os, 1998).

Since a few years a new system for tomato and cucumber is coming up in the Netherlands: suspended or raised troughs. Originally one grower installed the suspended troughs, because of problems with his soft peaty soil. The soil was not stable and, consequently, draining from slabs irregular. The system consists of coated metal troughs hanging at a height between 20 cm and 200 cm from the trusses. The troughs can be filled with an enveloped rockwool slab or perlite bag. Sometimes the troughs can be hoisted, but mostly they are at a fixed height. The main advantages are independency of the soil, water contents of substrate is more equal, interplanting in winter results in a longer season, better labor conditions, and continuous biological pest control. Of course there are disadvantages: expensive, especially when trough can be hoisted, no empty greenhouse, no cleaning and less efficient radiation from the heating pipes. Another important issue is the extra load on the greenhouse structure.

<u>To be continued in a subsequent volume</u>

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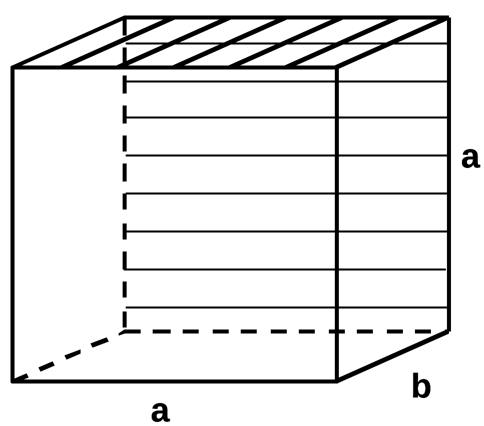
SCREENING BUGS OUT OF YOUR GREENHOUSE

Mechanical fan ventilation systems provide the grower the opportunity of screening out undesired pests while retaining beneficial insects. When the systems are properly designed, there is no adverse effect on the greenhouse ventilation and cooling system. The key to effective and efficient design is to learn the properties of the insect screen at various air flows through the screen. The most important property is static pressure drop or loss at a particular air velocity through the screen. Our screen designs use a computer program developed by Dr. James Baker and Mr. Ed Shearin at North Carolina State University. This design procedure suggests that a pressure drop of 30 to 50% of the fan's static pressure capability can occur through the screen.

Insect screens by their very nature limit air movement and provide an engineering challenge to exclude insects and not decrease the efficacy of the installed mechanical ventilation system. Fans used for greenhouse cooling are typically of low pressure design with an operating range up to 0.125 inches of water static pressure. These fans are designed for moving up to 20,000 CFM per horsepower at low static pressures, but are unable to move air at higher pressure differences..

The type of insect to be excluded, the fans used, and the area of the ventilation inlet of the greenhouse are entered into the computer model. The output of the model is the square footage of screening required for the type of insect to be excluded and several commercial screens available. Once the square footage is known and the screen selected, Figures 1 and 2 illustrate how the required screening could be applied to the greenhouse. Figure 1 shows a typical inlet box built over a standard greenhouse shutter intake and providing 40 square feet of inlet screen area. Figure 2 shows how a screen could be installed in a larger gutter connected greenhouse with a continuous vent window. The screen is attached to the window sill and to the bottom of the window.

If you are considering installing insect screening get in touch with your editor and he will run the program for you and make some suggestions on how you can successfully accomplish the desired task.



Screen area = (a x a) + 3ab
When a = 4' and b = 2':
Screen area = 16 + 24 = 40 sq ft

Figure 1

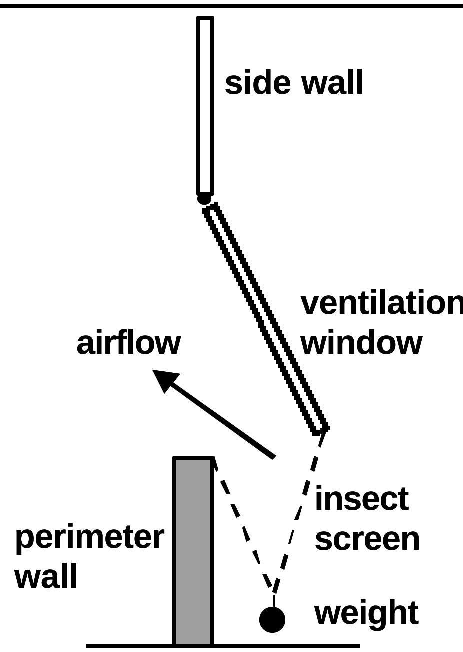


Figure 2

Standby Electric Power Equipment

Emergency equipment is essential to all greenhouse operations. Power failure as a result of a storm or because of equipment failure is a serious a concern for any grower. Power failures on a cold winter night will cause failure of most heating systems and without emergency standby electric generation equipment, the entire greenhouse crop can be lost in a few hours.

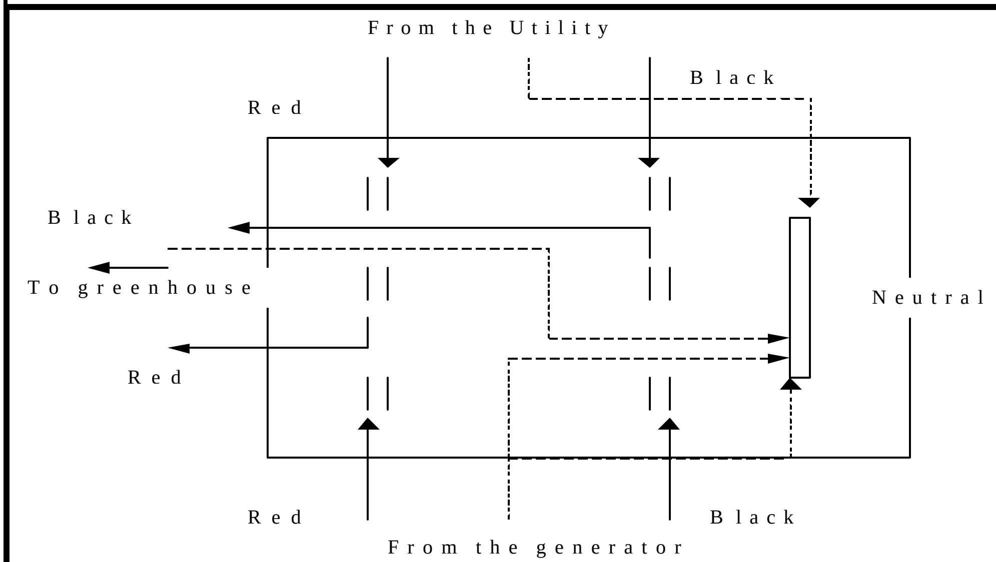
Standby equipment gives peace of mind knowing that you can keep essential equipment operating, whether it is (part of) the heating and/or ventilation system.

When selecting generation equipment, commonly called alternators, make sure that it matches the electrical service provided by your utility company. Normally this is a 120/240 volt single phase service. If three phase service is required, check the exact type with your electric utility.

Once a standby generation system is in place, a good maintenance and testing procedure is to operate it once a week . This helps to ensure that the equipment will be functional when needed in an emergency.

From a safety standpoint the installation of a double throw transfer switch, as shown in the figure below is mandatory. The danger is to connect a generator directly to the incoming utility lines after the power failed. This puts the utility lineman at great risk because the lines they are trying to repair can actually be charged from incorrectly connected emergency equipment. The working conditions for the lineman are hazardous enough without having to deal with power from emergency generation equipment. Permanently installed emergency equipment with proper switches do not pose this problem. Portable generators which often are directly plugged in to the distribution system are the greatest hazard

All emergency equipment should be installed by a licensed electrician. Bulletin number 2273, "Standby Electric Power Equipment for the Farm and Home" is a valuable source of information dealing with emergency power equipment. It is available free of charge from your Editor.



Emergency Generator System Switch Diagram of a Double pole - Double throw switch.
Neutral lines are attached to a common bond.
If three phase power is used, a triple pole — double throw switch is required.

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COOK COLLEGE
RUTGERS, THE STATE UNIVERSITY
NEW BRUNSWICK, NJ 08901

HORTICULTURAL ENGINEERING

Dr. A.J. Both
Assistant Extension Specialist
Director of CCEA
Bioresource Engineering
Rutgers, The State University of NJ
George H. Cook College
20 Ag Extension Way
New Brunswick, NJ 08901-8500
Your comments, questions, and suggestions are always welcomed.
Phone (732) 932-9534
email: both@aesop.rutgers.edu
Web: http://aesop.rutgers.edu/~horteng

Horticultural Engineering on the Web

This Issue of Horticultural Engineering, like previous ones, will soon be available on the internet at:

http://aesop.rutgers.edu/~horteng

If you prefer, we will send an e-mail announcing new Horticultural Engineering Newsletters as they are posted on our web site.

Thanks to those of you who have elected to receive this newsletter via the Web. We appreciate your help saving duplicating, postage, and handling costs in our department, particularly since our staff has been greatly diminished.

Our open-roof greenhouse was recently out-fitted with acrylic sidewalls (16 mm). The roof segments are clad with double-poly. A heated ebb and flood floor was installed last fall. We are hoping to install the heater (gas-fired hot-water system) and finish the sub-irrigation system during the next several months. The renovation work is directed by Eugene Reiss (Program Associate) and he is assisted by two undergraduate students: Tim Vadas and James Anderson. Let us know when you are visiting New Brunswick and we would be happy to give you a personal tour of this greenhouse facility.