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Preparing for Spring

Maintenance is often that practice most neglected because of great activity and a busy schedule. The early winter months offer opportunities to get the transplant production facilities ready for the intensive spring planting season. Your editor will be speaking on Thursday, January 18, at the New Jersey Vegetable Growers Meeting in Atlantic City on **Readying and Preparing the Greenhouse for the Spring Season.** In this issue we feature an article by Professor Emeritus Bill Roberts on this subject and also an article by Dr. Sase concerning the Japanese greenhouse industry presented at **ACESYS IV**

New Publication: Insect Exclusion from Greenhouses

While controlled environment facilities have been used to grow plants for many purposes, biological security is not always a design requirement. In recent years the commercial greenhouse industry has shown increased interest in reducing infestations of insects and disease. Some research facilities and government agencies operate quarantine facilities, which have long required biological safeguards. The design of both commercial production greenhouses and quarantine facilities can benefit by careful integration of some of the principles of both. The paper discusses the relatively new concepts for quarantine greenhouse facility design and then reviews some of the significant developments in insect exclusion from commercial facilities. Finally, some concepts are presented that hold promise to further increase the effectiveness of insect exclusion from commercial greenhouse production facilities.

Contact us to receive your copy.

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. Four Rutgers or former Rutgers Professors were invited speakers to this important international event. The conference was translated simultaneously from English to Japanese and was held in Tsukuba Japan, North of Tokyo. Drs. Mears, Ting, Giacomelli, and Roberts participated. Organizers were very pleased with the success of the conference.

Water and Nutrient Management for Greenhouses NRAES 56

The crop root zone consists of roots, water, air, nutrients and organisms. These all comprise the environment of a plant at a particular temperature.

NRAES 56 written by Dr. Tom Weiler of Cornell University is an excellent publication describing the complex interaction of the root and aerial environment of a plant growing system. The 102-page manual deals with these complex issues in 9 chapters which include:

- Crop Nutrient Needs
- Water Basics: Analysis and Delivery
- Fertilizer Basics, and Analysis
- Fertilizer Proportioners
- Substrate Basics and Analysis
- Temperature, Aerial, and Root Zone

This valuable publication is available from:

NRAES Cooperative Extension
152 Riley Robb Hall
Ithaca, NY 14853
Phone 607 255 7654
Fax 607 254 8770
http://www.nraes.org

ACE-SYS IV International Conference

Paper review.

The following is a condensed version of a paper presented by Dr. Sadanori Sase at the 4th ACE-SYS Symposium. Single copies of the complete paper are available from your Editor. Copies of the entire Proceedings are also available from Dr. Sase, Convener of the Symposium.

Current Status and Technological Perspectives in Greenhouse Environment Control under Mild Climate

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1. Introduction

Greenhouse production is expanding in the regions under mild climate. Year-round production in greenhouses is one of the primary concerns to increase efficiency and productivity. The production of plants which require lower growing temperatures is increasing. The technologies to cool greenhouse air on hot sunny days have been becoming more important. Particularly, natural ventilation systems which are significantly less energy intensive than fan ventilation systems have been widely adopted. The improvement of performance of natural ventilation systems has been of great interest all over the world. Open-roof greenhouses have recently been introduced as a solution. Cooling is important from a viewpoint of reducing the thermal stress of workers in greenhouses. The total area of greenhouses in Japan is over 53,000 ha. However, most of the greenhouses, which are pipe-structured and covered with plastic films, are not highly sophisticated. The scale of production of each grower is small. Another critical issue is to reduce the environmental impacts due to pesticides and fertilizers emitted from greenhouses as well as the management of used plastic films. Efforts for more sophisticated greenhouse systems to meet these requirements must be needed.

This paper describes the current technological status in greenhouse environment control in Japan, the basis of cooling greenhouse air, the characteristics and feasibility of natural ventilation in terms of temperature rise and air distribution, and evaporative cooling under natural ventilation. Thermal comfort in greenhouses is also discussed to reduce the heat stress of workers.

2. Current status of greenhouse environment control in Japan

The total area of greenhouses in Japan reached 53,518 ha in 1999 (MAFF, 2000). This area excludes rain shelters (13,571 ha) and low tunnels (46,503 ha). 77% of greenhouses are covered with polyvinyl chloride (PVC) films while the area of glasshouses is only 4.6%. The use of PVC films has slightly decreased recently. Other plastic coverings such as polyolefin (PO) films have been increasing for long-term use. 79% of greenhouses are pipe-structured, which are not highly sophisticated.

Table 1 shows the overview of technologies adopted for environmental control in Japanese greenhouse industry. 44% of greenhouses are equipped with thermal screens, 32% with single-layer and 12% with multi-layer. 43% and 27% of greenhouses are equipped with heating systems and automatic irrigation systems, respectively. 96% of heated greenhouses use oil as an energy source and 76% have thermal screens. Hot air heaters are quite popular while 88% of heated greenhouses are equipped with hot air heating systems. The advantages of hot air heating systems are high energy efficiency of 85-90%, quick response for temperature control, low cost and easy maintenance. Although the heated greenhouse area has increased, the oil consumption for greenhouse production has remained almost constant and it is estimated to be approximately 1,500 ML/year (1992) through the adoption of thermal screens and hot air heating systems.

It is noted that the growth rates in the greenhouse area equipped with ventilation fans, multiple temperature set point control and automatic ventilator control in the past two years are around 10%, respectively. The number of computers used for environmental control has increased from 2,610 to 4,312 in the same period. These indicate that growers have paid more attention to ventilation control and more precise control in temperature as well as other factors. The reduction in cost of computerized controllers is another reason.

3. Basis for preventing excessive rise in greenhouse temperature

Preventing an excessive rise in greenhouse temperature is very important particularly under mild climate. Typical methods to prevent the excessive temperature rises are ventilation to exchange internal air with cooler external air, shading to decrease incoming solar radiation, and cooling. Both ventilation and shading can not achieve the lower internal air temperature than the external air. To cool the internal air below the external air, evaporative cooling technique is the most practical and inexpensive in operating cost. Shading and/or evaporative cooling systems function well in combination with ventilation.

The phenomenon of natural ventilation is complex and its design is more difficult than fan ventilation. Natural ventilation is induced by external wind force (wind effect) and buoyancy force (chimney effect) based on the temperature rise (temperature difference between internal and external air). In theory, the natural ventilation rate varies linearly with external wind velocity and area of ventilation openings, while it also varies linearly with the square roots of height of openings and temperature rise. For the design purpose, wider openings are effective in increasing the ventilation rate. The total area of openings is recommended to be 15-25% of the floor area of a greenhouse in general.

It should be noted that the temperature rise does not linearly decrease as the ventilation rate increases. The heat balance analysis of greenhouses shows that it varies with the reciprocal of ventilation rate under a steady-state condition in the day. When the temperature rise is below 3 °C, the increase in ventilation rate does not result in remarkable reduction in the temperature rise, for example.

The temperature rise is nearly proportional to the sensible heat converted from incoming solar radiation. The purpose of shading is to reduce the energy input of solar radiation. White or aluminized shading materials which reflect solar radiation are recommended, when they are installed inside a greenhouse. The materials such as black-colored absorb solar radiation and contribute to the temperature rise by releasing the absorbed heat into the greenhouse space. To prevent it, external installation of shading materials is an ideal practice. There has been considerable interest in the glazing materials which can selectively reflect or absorb the infrared region of solar radiation. Efforts in developing such covering materials have been in progress. Some films with such properties are commercially available. However, a disadvantage of the films is a reduction in the region of photosynthetically active radiation.

The absorbed solar energy in a greenhouse is converted into sensible and latent heats. The latent heat converted through evapotranspiration does not affect the temperature rise. Thus, the decrease in sensible heat may prevent the temperature rise as the increase in evapotranspiration under a constant solar radiation.

4. Effects of greenhouse height and ventilation opening area on temperature rise under natural ventilation

Recently, the eaves height of large-sized multi-span greenhouses such as Venlo greenhouses has been increased. The taller height resulting in greater greenhouse capacity may prevent the quick change in environment and improve the spatial uniformity. Other advantages are to promote the ventilation caused by chimney effect and the mixing of cooler incoming air through roof ventilators with internal air, because the location of roof ventilator openings is raised. When the side walls with high eaves are widely opened, external wind promotes horizontal airflow through the space above plants. However, the area of side openings per greenhouse floor area decreases as the width of a greenhouse increases. Therefore, the roof ventilators are more important for large-sized greenhouses, especially the increase in the area of roof ventilator openings. Recent introduction of open-roof greenhouses allows the roofs to be entirely opened.

Fig. 1 illustrates the effect of height of roof ventilator opening on temperature rise (difference between internal and external air) for a greenhouse with no opening on side walls (Sase and Okushima, 1998). This was obtained computationally by combining a simple statistical relation proposed by Kittas *et al*. (1997) with a heat balance equation under a steady-state condition. The ratio of roof ventilator opening area to floor area was 0.2. It was found that the temperature rise decreased as the height of roof openings increased. When no external wind existed, an increase of 1 m in the height yielded a reduction of approximately 0.5 °C in the temperature rise under high solar radiation. While the temperature rise decreased with an increase in wind velocity, the effect of the increased height of roof openings decreased with an increase in wind velocity. For example, the reduction in temperature rise for an increase of 1 m in the height showed approximately 0.1 °C at a wind velocity of 2 m/s. This was mainly because the wind force on openings is not affected significantly by the height of roof openings, and the ventilation caused by wind force is dominant to the ventilation caused by buoyancy force at a range of wind velocity.

Fig. 2 shows the effect of roof ventilation opening area on the temperature rise at an opening height of 4 m (Sase and Okushima, 1998). This was also obtained computationally in the same way as Fig. 1. It was found that the temperature rise decreased exponentially with increasing the ratio of roof ventilator opening area to floor area. In other words, the temperature rise decreased quickly with an increase in the ratio of opening area when it was less than 0.4 or 0.5, while the effect of the increased ratio of opening area was less significant when greater ratio of opening area. It is evident that the wider openings such as those of open-roof greenhouses are required in order to minimize the temperature rise.

Editor's note ***The following topics were also discussed in the paper but were omitted for lack of space.***

5. Spatial distribution of airflow and temperature under natural ventilation
6. Evaporative cooling for naturally ventilated greenhouses
7. Thermal comfort in greenhouses

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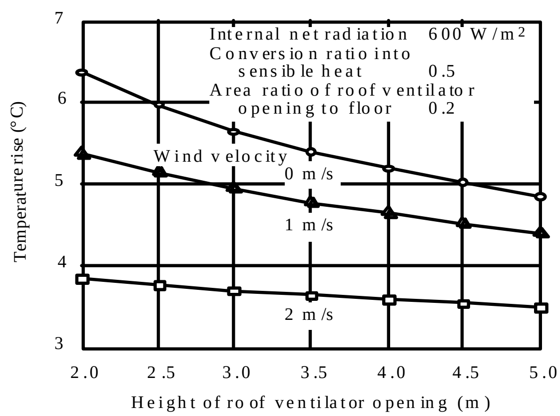

Fig. 1. Effect of height of roof ventilator opening on temperature rise (Sase and Okushima, 1998).

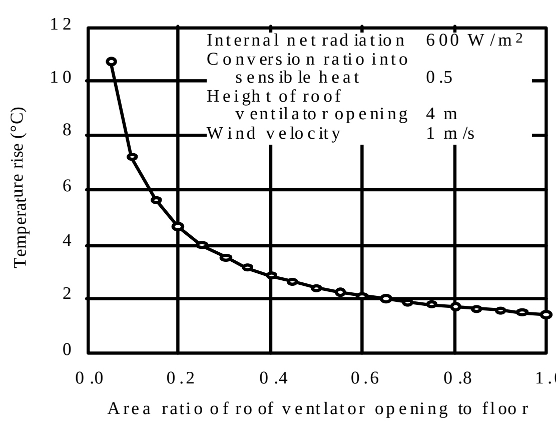

Fig. 2. Effect of roof ventilator opening area on the temperature rise (Sase and Okushima, 1998).

Table 1. Overview of technologies used for environmental control in commercial greenhouses in Japan

	Area in (ha)	Ratio to total area	Growth in past 2 years
Thermal screen	23,521	43.9 %	1.6 %
Heating	23,175	43.3 %	4.2 %
Automatic Irrigation	14.508	27.1 %	-3.5%
Ventilation fan	9,974	18.6 %	10.9 %
Multiple temperature set point control including adjustment of set points based on solar radiation	9,792	18.3 %	9.0%
Automatic control of side and roof ventilators	5,021	9.4 %	11.2 %
Number of control computers	4,312		65.2 %
Total greenhouse area	53,518		1.8%

TUNING UP THE GREENHOUSE FOR SPRING

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The late winter and early spring are a good time to prepare the greenhouse for dependable operation during the transplant growing season. The integrity of the glazing is always important but the following are a series of bullets which deal mostly with the environmental control system for the greenhouse, an indispensable component of the greenhouse production system. Now is the time to check them all out and help prevent those devastating breakdowns.

Heating Systems:

- Inspect exhaust systems
- Inspect combustion air inlets
- Check the integrity of the combustion chamber
- Clean hot water boilers
- Have exhaust gases analyzed for temperature and CO content.

Exhaust Systems:

- Replace defective exhaust stack, particularly sections within the greenhouse.
- Horizontal runs of stack should pitch upward at least 1/4 inches per foot.
- Exhaust stack should extend at least 24” higher than the highest roof line nearby. See Figure 1.

Exhaust Stack Location

Stack should be 24” above
The nearest ridge of the
Greenhouse or adjacent
buildings

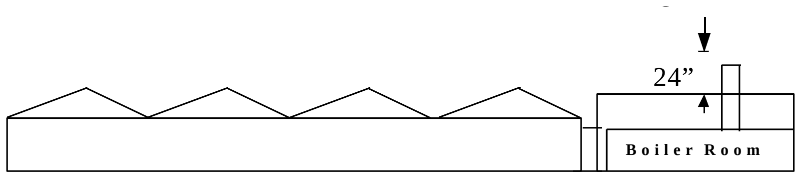

Figure 1

Combustion System:

- Fresh air supply should be provided directly from outside of the greenhouse
- Provide 1 square inch of opening per 2000 Btu/hr output of the heating unit.
- Example 200,000 Btu/hr unit requires 100 square inches 8.5" by 12" for instance.
- An exhaust air directional device on the top of the stack is needed for windy locations or a forced air draft fan, either of which can prevent back draft and potential contamination in the greenhouse.

Separated Combustion:

- Separated combustion units separate the two air handling systems, combustion air enters from outside and is used within the heat exchanger for combustion and then leaves through the exhaust stack. Greenhouse air which is drawn through the heat exchanger to be heated enters the unit and then leaves the exchanger never having come in contact with any combustion process.
- This eliminates greenhouse air with contaminants from entering the high temperature combustion chamber and causing possible damage to the heat exchanger.

Boiler Care:

- Have an approved maintenance contractor check exhaust air for temperature and Carbon Monoxide (CO) content. Temperatures too low can create corrosion problems because of condensation in the exhaust stack. Temperatures too high waste energy.
- CO levels determine the efficiency of the combustion process
- Clean boiler tubes to increase heat transfer from the exhausting gases to the hot water tubes.
- Check pump operation, electrical protection devices and switches including thermostats.
- Check system for leaks and insulation damage, especially next to the boiler.

Fuel Storage Precautions:

- Ensure proper propane tank size to prevent icing in cold conditions caused by the evaporation of the liquid gas within the tank. When the tank ices the area for heat transfer is reduced and less gas is vaporized and available to the heating system. This occurs at a time when you need heating the most.
- Above ground oil storage tanks require treatment for the oil in very cold weather to keep the oil from solidifying and not being able to be pumped to the burner.
- Above ground storage tanks in many localities need a perimeter berm to contain a full tank of fuel in case of a leak in the tank.

Ventilation Systems:

- Ventilation systems often comprise fans, controlled inlets and some form of control system such as thermostats or computer. Aspirated thermostats are best. See Figure 2.
- Controlled interaction between the heating and ventilation systems is imperative when used for humidity control in cold weather operation.
- Exhaust fans can draw unit heater exhaust fumes into the greenhouse potentially causing serious epinasty of the crop being grown.
- Separated combustion units as mentioned earlier can totally eliminate this problem.
- The heating and ventilation control can be electrically interlocked so that the ventilation fans cannot operate when the heating system is operating.
- Electrical time delay devices can also provide protection by delaying the starting of the ventilation fan until the motorized inlet has been completely open. This reduces the negative static pressure which can occur when the fans first start and the motorized shutters have not yet fully opened. This also takes the load off the electrical motor powering the shutters and allows them to open more easily.

Ventilation Equipment Care:

- Check the belt tension on exhaust fans.
- Polished sheaves indicate that the belts have been slipping.
- Provide 1/2” slack in the drive belt at a distance one half way between the driven pulley on the fan and the driving pulley.
- Check fan shutters and motorized inlets for damage. Sticking open or closed can cause problems with the ventilation system, particularly in cold weather.

Ventilation Components:

- Provide one square foot of controlled inlet for each 1000 cfm of air exchange.
- Provide at least one two-speed fan for greenhouses with only one or two ventilation fans.
- Control inlets to provide sufficiently high air velocity through the inlet in winter to promote good mixing of cold incoming air with the ambient greenhouse air. This inlet can be sized to give an apparent velocity of 700 feet per minute. See Figure 3

Emergency Equipment:

- Have a warning system which will give an alert in the case of a system failure, such as very high temperature or low temperature.
- This alert system should be connected to the grower or manager’s residence so that someone can act upon the warning.
- Have an emergency generator of a size large enough to operate heating equipment and some of the ventilation fans separately.
- Operate the emergency generator system regularly, such as once a week so that it will operate in times of emergency.

Aspirated Thermostats

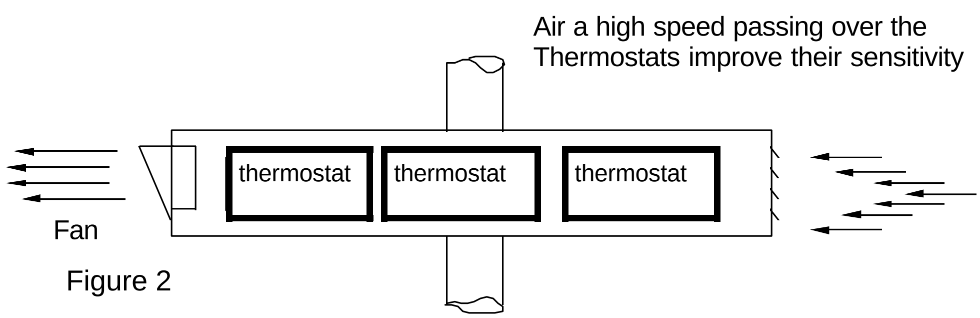

Figure 2

Controlled Ventilation Inlet Design

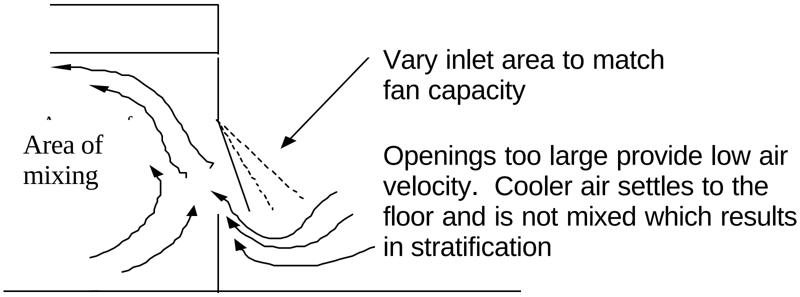

Figure 3

COOPERATIVE EXTENSION
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HORTICULTURAL ENGINEERING

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Horticultural Engineering on the Web

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We will send an e-mail announcing each Horticultural Engineering Newsletter as it is posted on our web site.

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

New Jersey Annual Vegetable Growers Meeting

January 16-18, 2001
Trump Taj Mahal Casino Resort
1000 Boardwalk at VA. Ave.
Atlantic City, New Jersey

The meetings feature the 45th Annual Trade Show, one of the best in the East. There will be a special Greenhouse transplant session on, Thursday morning January 18, at 9:30. Speakers include your Editor, A. J. Both, speaking on Readying your Greenhouse for the Spring Season, Dr. Wes Kline on common problems in transplant production, Jim Willmott discussing concerns with growing media and Dr. George Hamilton speaking on required compliance with pesticide applications. Pesticide Recertification Credits will be available at the conclusion of the program. Robert Moore will give an update on what's new in the industry.

Plan now to attend this excellent meeting and meet the vendors at the trade show and your friends and neighbors from the industry. Registration information is available from: ***Mr. Phil Traino***
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Marlton, NJ 08053