CCEA Newsletter

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CCEA is a research organization dedicated to the improvement and vitality of the Controlled Environment Agriculture Industry. CCEA is funded by Industrial and Grower Partners who contribute a yearly partnership fee. Satellite partnership is also available to growers. Information about **CCEA** is available from:

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Vision Statement

CCEA, The Center for Controlled Environment Agriculture of NJAES of Rutgers University, a partnership among growers, industry, and researchers, will devote itself to research and transferring information required for an economically viable and environmentally aware controlled environment agriculture industry. We will particularly strive to identify future trends, critical issues, appropriate emerging technologies and provide leadership for opportunities which challenge world-wide controlled environment agriculture in the 21st century.

Open-Roof Greenhouse

Significant progress has been made with the renovations of the open-roof greenhouse located on one of the research farms near Campus. After completion of the heated ebb and flood floor, all sidewalls were re-glazed with twin-walled acrylic sheets (16 mm thick). In addition to the open roof, side vents were installed along the west and east walls. These sidewalls will allow for ventilation when the roof is unable to open (e.g., due to rainy or windy conditions). We are in the process of reinstalling some of the inside sensor which were temporarily removed for the renovations. Over the next several months, we are planning to finish the installation of a gas-fired hot-water heater (supplying hot water to three zones: floor, perimeter and overhead pipes), and the pumps and controls for the two separate but identical floor irrigation systems.

The renovation work is conducted by Eugene Reiss (Program Associate) with help from two undergraduate students: Tim Vadas and James Anderson. Two pictures of the open-roof greenhouse are shown on the last page of this newsletter. Please let us know when you are visiting our area and we will be happy to give you a personal tour of the greenhouse facility.

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. Organizers were greatly pleased with the success of the conference. Presented papers included: "Current Status and Technological Perspectives in Greenhouse Environment Control under Mild Climate", Dr. Sadanori Sase, of NRIAE Japan; "New Developments in Recirculation Systems and Disinfection Methods for Greenhouse Crops", Mr. Erik van Os of IMAG, the Netherlands; 'Effective Environmental Control for Greenhouses", Dr. Lou Albright of Cornell University; "Object Oriented Analysis for Controlled Environment Agriculture", Dr. K.C. Ting of Ohio State University; "Closed Transplant Production Systems with Artificial Lighting for Production of High Quality Transplants with Environmental Conservation and Minimum Use of Resources", Dr. Toyoki Kozai of Chiba University, Japan; "Insect Exclusion from Greenhouses", Dr. David Mears of Rutgers University and many other cutting edge papers. Of the 12 speakers, 5 are members of our CCEA faculty or the Scientific Advisory Panel. Dr. Sase indicated that copies of the complete proceedings are available from him. His contact information is:

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Engineering Aspect of Innovative Growing Systems

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The following is an excerpt from a paper presented by Dr. Gene Giacomelli at the ACESYS IV International Conference in Tsukuba Japan, December 2000. Single copies of the paper are available from the editor.

1. Micro Gravity Pocket

The micro gravity pocket [MGP] was developed by Mark Lefsrud (Lefsrud et al., 2000) as a potentially new nutrient delivery system [NDS] for micro gravity situations. The two currently used root nutrient delivery systems for growing plants in micro gravity are the porous tube and soil matrix (nutrient packet) (Hoehn et al., 1998; 2000; Dreschel et al., 1993). Each system has been successful for several crops, yet each maintains problems for growing and harvesting root crops. Removal of roots from a soil matrix results in the potential loss of containment of the soil particles. Free soil particles in micro gravity are a serious concern for spacecraft functions and crew health. The porous tube has no soil matrix. Root crop development has been demonstrated on the porous tube but production procedures have not been sufficiently developed for application.

The Micro-gravity Pocket [MGP], was designed for NASA for the growth of root crops within the Salad Machine. The Salad Machine is named after the technique of continually supplying fresh green salad plant crops during space travel. The water and nutrient delivery system is one of the major design challenges that need to be resolved for the successful implementation of the Salad Machine. The NDS must be able to deliver sufficient water and nutrients to the plant roots in micro gravity conditions, without over-watering and potentially causing anoxic root-zone conditions. There are currently six major types of watering systems that have been considered for use in space. They range from a: saturated foam, agar, zeolite/balkanite, nutrient pack with aggregate, and two kinds of porous tubes (ceramic and metal) with or without matrix. The nutrient pack, porous tubes and zeolite systems have proven to be the most promising methods of growing plants in micro gravity.

The MGP is lightweight, easy to seed, and harvest. Containment of the root zone was achieved, and operational energy requirements were very low. The MGP uses two sheets of hydrophilic plastic, which wick nutrient solution from a small, very local reservoir into the porous plastic **[Figure 1]**. The pocket dimensions are 6 cm by 28 cm by 0.5 cm [2.3 by 11 by 0.2 in]. The reservoir tube is 1 cm in diameter. The plastic provides support, structure and delivers nutrient solution to the plant roots. Three types of plastic sheets, varying in thickness and pore diameter, were used in the prototype MGP. These included plastic screening [0.1mm [0.004 in] hole size] and two types of hydrophilic polymer sheets.

The first prototypes used plastic screening on polyurethane foam backing, which could wick water to the roots. Subsequent designs used manufactured plastic sheets with very small pore sizes from Porex Technologies®. These plastics were hydrophilic removing the need to use the foam. The foam backing was created by cutting two foam blocks [30 by 10 by 2 cm thick] [12 by 4 by 0.8 in] which were glued to the screening, so that the two foam blocks could be folded on top of each other and form a sandwich with the screening in the inside. A hydrophilic polymer (material able to absorb over 50 times its weight in water) was placed between the screen and the foam. The screening was then sealed along three edges, forming a pocket where the plants could grow. On the opposite side of the screen, a plastic tube [0.5 cm [0.2 in] diameter] was cut length-wise and placed on the foam. The plastic tube allowed water to flow from a water supply tube at the open end of the pocket, along the back of the foam, and be collected at the long closed end. A 1 cm [0.4 in] diameter black rubber tube was used to collect the water and return it to the nutrient tank. A black polyethylene plastic sheet was then glued to the outside of the pocket to prevent water leakage and to prevent light from reaching the roots. Aquarium silicon was used to 'glue' everything in place.

The roots grew in contact with the screen but were also able to grow through the screen and into the foam and the return water tube. This resulted in poor containment of the roots. Although the plants were able to reach full maturity and produce a storage root using the plastic screen, all future designs used only the plastic polymer sheets so that the roots would be properly contained within the pocket.

2. Porous Tube Nutrient Delivery System

The porous tube nutrient delivery system was conceived and developed by Dreschel et al. (1988) for NASA for food production in space. The porous tube may be manufactured as a 2 cm [0.8 cm] diameter, hollow ceramic tube, with a 0.5 cm [0.2 cm] thick wall **[Figure 2]**, or alternatively, it may be constructed from a solid rod containing six, 0.5 cm diameter internal channels that span the length of the rod. The latter construction was used in these experiments (Lefsrud, et al, 2000). The ceramic has fine pores [0.25 to 1.0 mm]. The pores allow water to move from the inside of the tube to the outer surface by capillary action. Suction pressure can be used to restrict the capillary flow and control the amount of the water film which collected on the outer surface of the porous tube. If a small negative or suction pressure is exerted on the tube, then the water will not flow from the tube. This suction pressure will cause any free water that is on the surface of the tube to be drawn back into the tube. The proper balance of these two forces will allow a thin film of water to remain on the surface of the porous tube and become available for the root system of the plant.

To provide the nutrient solution to the porous tube at a continuous and highly accurate suction pressure, a siphon-standpipe configuration was constructed as shown in **Figure 3**. Water was pumped into the standpipe tube to create a constant elevation head. A smaller pipe transports nutrient solution into the porous tube and returns excess to the tank. The vertical distance between the water level in the standpipe and the porous tube creates the suction pressure. By controlling the pump flow, the water level in the standpipe is maintained at the desired height [and subsequent suction pressure] relative to the porous tube.

The thin film of water that occurs on the porous tube is the only source of water for the plants. The roots are not able to penetrate the tube and must remain in contact with the tube to absorb water directly from the surface. Therefore roots, in direct contact with the tube have the most accessible water, and as the root mass increases, the outermost roots have little or no access to the water film on the porous tube.

A variety of crops have been grown in previous research with the porous tube, including wheat, beans, rice, white potato, radish, pea, soybean, sweet potato, lettuce, and tomato.

A comparison of the porous tube with the MGP consisted of two tests with four plants per NDS per test. The plants selected for growth on the porous tube and the MGP were radish, carrot, and beet. Radish was grown to confirm that the porous tubes were functioning properly (Dreschel et al., 1992). The carrot and beet crops were successfully grown on the porous tube. No data for these crops are provided in this paper.

The results for radish **[Table 1]** indicate that the MGP produced on average a slightly smaller plant based on the measured fresh and dry weights. However, the (wet) mass of the edible storage root was the same in each system.

Table 1. Wet and dry mass (grams) of radish grown in the porous tube and MGP

Nutrient Delivery System	Total Wet Mass	Total Dry Mass	Storage Root Wet Mass
Porous Tube	21.2 g	1.7 g	7.0 g
Micro Gravity Pocket	15.9 g	1.3 g	7.0 g

3. Aeroponic Production of Burdock, a Medicinal Root Crop

An aeroponic nutrient delivery system was designed as a prototype commercial production unit for the aeroponic production of medicinal root crops in greenhouses. Burdock [Arctium lappa] a deep-rooted biennial plant was successfully produced within the system.

The advantages that aeroponic production provided for this crop were: ease of access to the long roots, ability to obtain secondary roots which are typically lost during harvest in soil systems, clean root material that is free of soil-borne organisms, and no concern for introducing an invasive weed to a new location. Other benefits related to the aeroponic system within a controlled environment included: potential for a more consistent plant growth and production of secondary metabolites, year-round production, higher plant densities, improved nutrient and water management, potential for mechanical harvesting, and potential of multiple harvests from one crop

The aeroponic unit consisted of a 3.2 cm [1.25 in] diameter PVC plastic pipe, “A” frame construction. Its rectangular base ‘footprint’ dimensions were 2.4 m by 1.7 m by 0.6 m [L x W x H, 8 by 5.5 by 2 ft], which supported two, plant growth frames mounted on the top of the base frame that created an A-frame cover that reached 1.5 m [4.9 ft] at the peak. The plant growth frames were constructed of 3.2 cm diameter PVC plastic pipe and were 1 m [3.3 ft] wide by 2.4 m [8 ft] long. The entire surface of the Aframe structure was covered with an opaque plastic film sheet to prevent light into, and water spray out of, the root zone, but allowed easy access for observing and harvesting the plant roots. The bottom of the frame was designed to collect the excess nutrient solution and return it to the nutrient solution storage for reuse.

Seedlings were germinated in rockwool cubes and transplanted through the plastic film cover of the plant growth frames [i.e., along both sides of the top of the A-frame] at a density of 11 plants m^{-2} [1 plant ft^{-2}] . The aerial portion of the plant remained above the plant growth frames, and the root zone of the plant hung within the space below the surface.

The nutrient solution distribution system consisted of three rows of 1.3 cm [0.5 in] diameter PVC plastic pipes mounted 25 cm [10 in] above the base of the rectangular frame. The nine nozzles with hollow cone spray pattern were spaced within the rows to obtain a uniform distribution of water spray to all plants. The nutrient solution for the system was pumped at a rate of 4.5 L min^{-1} [1.2 gal min^{-1}] from a 94 L [25 gal] storage tank located below the aeroponic production frame. The nutrient solution consisted of a modified one quarter strength Hoagland’s solution. The pH and EC were maintained at 7.0 and 1.0 mS cm^{-1}, respectively. A centrifugal pump, located outside of the nutrient tank, was operated continually throughout the night and day.

A copy of the complete paper is available from the editor

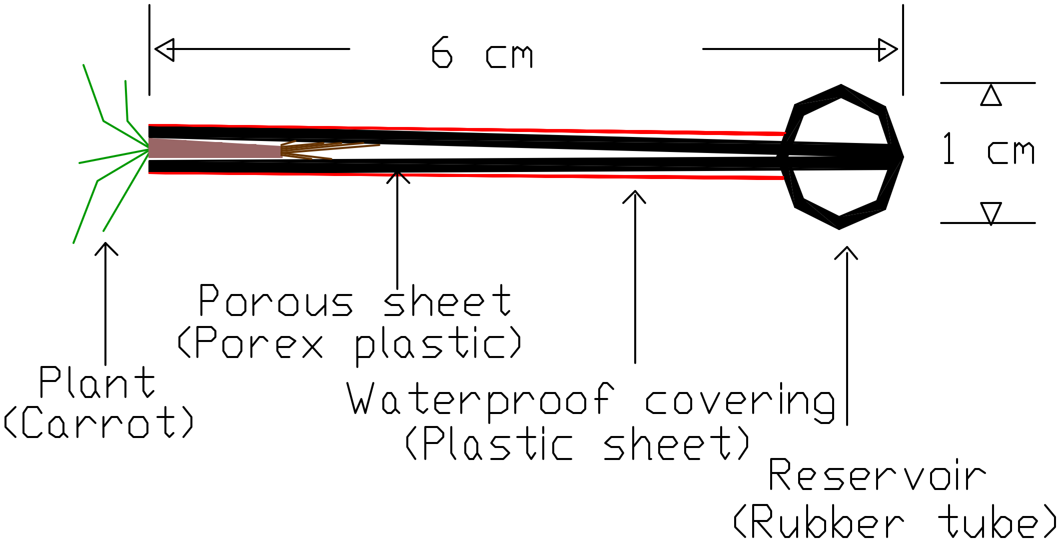

Figure 1. Cross sectional view of the

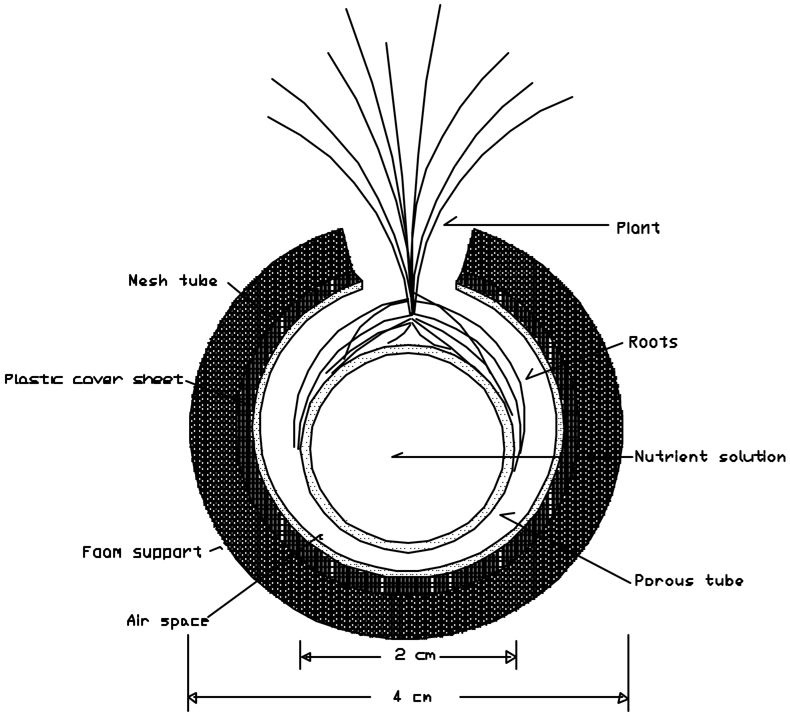

Figure 2. Cross sectional view of the Porous Tube Nutrient Delivery System.

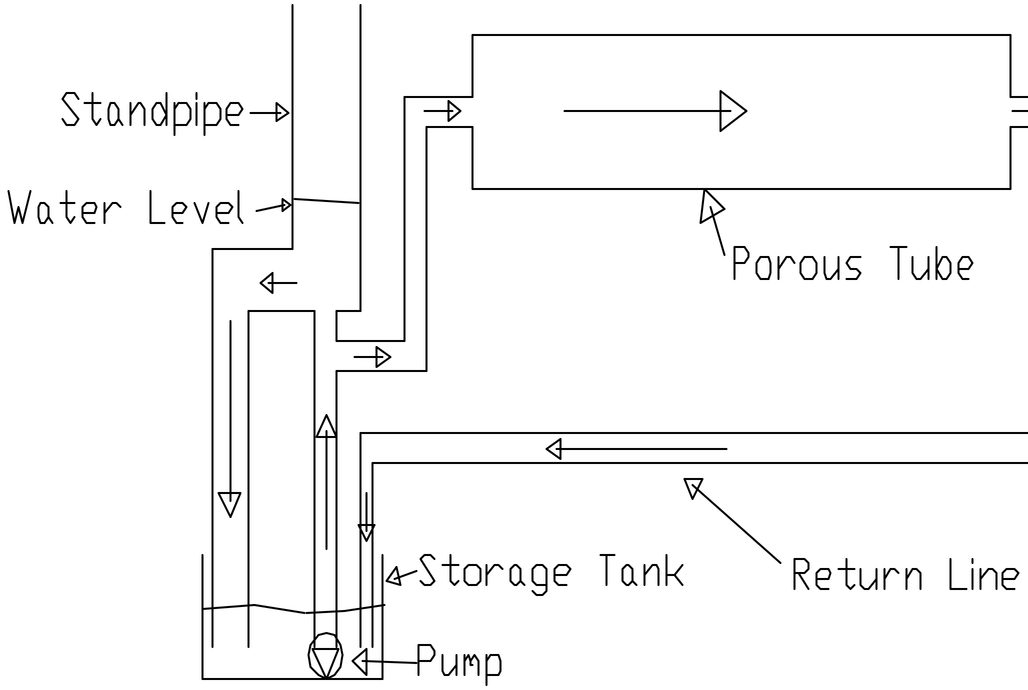

Figure 3. Siphon-standpipe configuration for providing the nutrient solution to the porous tube at a prescribed suction pressure.

Acknowledgement
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Interior view of the open-roof greenhouse. The sidewalls are twin-walled acrylic panels (16 mm thick), the roof segments are double poly. Note the snow on the roof near the gutter.

Exterior view of the open-roof greenhouse (East wall). The vertical portion of the East wall was outfitted with a continuous side vent. A similar vent was installed in the West wall.