Space age farm technology can feed the world

by Marcia Merry

Last winter there opened a new gallery at the Smithsonian Institution's National Air and Space Museum in Washington, D.C., titled "Where Next, Columbus?" devoted to scientific questions of voyages of discovery. Planned to run for the next five years, the exhibit features a "salad machine" of live, growing lettuce, to illustrate the challenge of how scientists are working on self-contained systems that will recycle wastes and nutrients, and provide the means to generate the necessities and amenities of life under harsh conditions of prolonged life in space. The "salad machine" lettuce grows hydroponically—in a nutrient water solution, for eight weeks, and looks delicious.

This Washington exhibit dramatizes the fact that in recent years, advances have been made in the techniques of controlled environment agriculture, or what is called "protected agriculture" of all types, to the extent that there is next to no place on Earth that food production could not take place, as long as the infrastructure were provided to meet the agricultural needs.

Over the last 30 years, all kinds of systems have been devised for cultivating plant growth, ranging from water solutions (usually referred to as hydroponics), to aeroponics (involving sprays and mists of nutrients applied to the plants), to nutrient film technique (NFT), to simple outdoor soil warming and pinpoint irrigation, plus many variations on these methods. In one experiment now under way in Arizona, the root balls of tomato plants are growing inside balloons, so that the roots define their own minimal space (see accompanying interview).

The requirements for inputs of energy, temperature, light, nutrients, structural support, etc., may be exacting, plus only a select few plant cultivars may be suitable (such as dwarf grains), but the yields are vastly higher than from common, open field agriculture. Because of this, "protected agriculture" (greenhouses, hydroponics, specialized irrigation), which require sizable start-up capitalization, may appear to cost more, but often these systems are in reality cheaper than lower-yield open field production, or long-haul "free trade" imports from afar. This may

Visitors and reporters crowd into a pavilion at Epcot Center, at Disney World in Orlando, Florida, on Oct. 2, 1987, for the dedication of the permanent exhibit featuring NASA research on food supplies for extended manned space flights. Crops are grown with hydroponics, nutrient film techniques, and other systems that could provide fresh vegetables for astronauts on future space missions.

go against common opinion, but it is demonstrable fact.

The two opposite poles of agricultural production techniques are customarily called controlled environment agriculture (CEA) and open field agriculture (OFA.)

NASA's Biomass Production Chamber

While all over the world there are certain research centers, scientists, and farmers whose efforts are focused on advanced agriculture systems, some of the most dramatic work today takes place in Florida at the John F. Kennedy Space Center, where the National Aeronautics and Space Administration (NASA) operates a facility for experiments in remote-controlled agriculture. The unit, shown in several photographs on the next page, is called the Biomass Production Chamber, in Hangar L on Cape Canaveral Air Force Station.

The Biomass Production Chamber is a key element of the Controlled Ecological Life Support System program (CELSS). In this NASA effort, researchers are developing the requirements for a regenerative life support system capable of sustaining long-term human stay in space. The challenges involve not only growing food, but also generating oxygen and recycling waste produced to fertilize the plants.

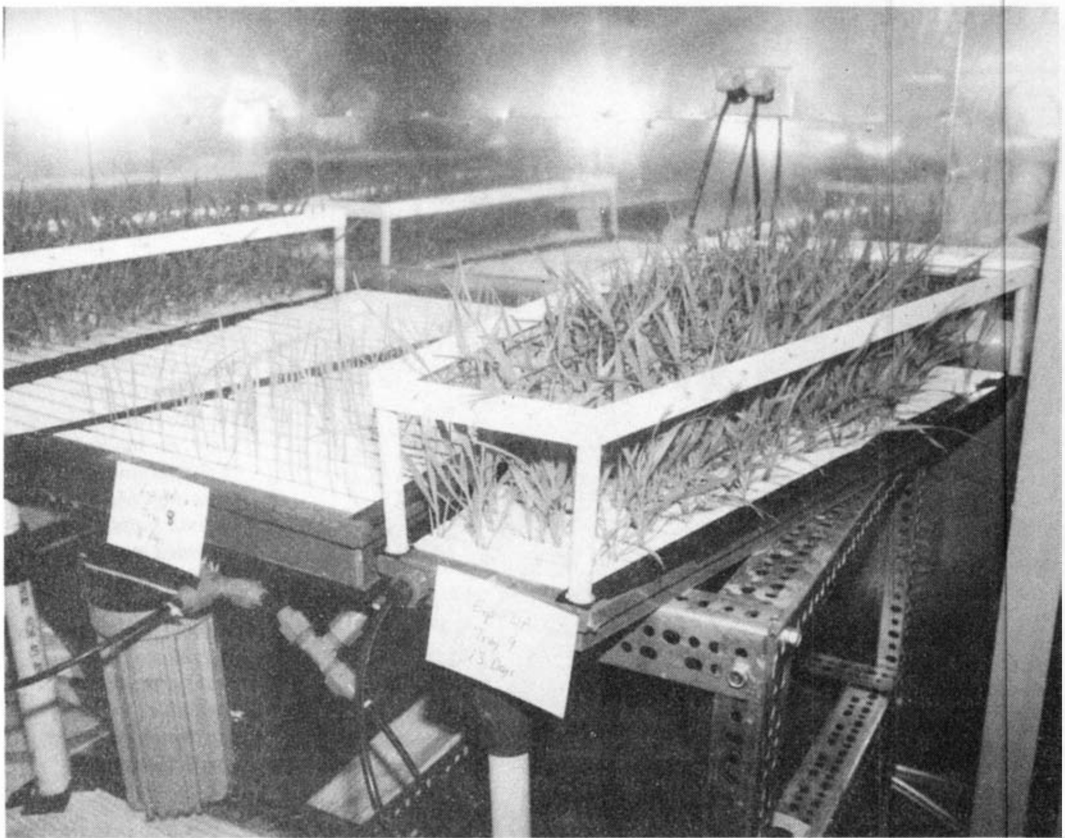
Since the inception of the CELSS Biomass Chamber in Florida, several experimental crops have been grown, including wheat, soybeans, potatoes, and lettuce. On Jan. 4, 1989, a harvest of dwarf wheat marked the successful conclusion of the first "sealed environment" experiments in which scientists attempted to grow food crops using remote control devices and computer monitoring.

Subsequent experiments are looking at continuous wheat production, where plants of various ages are growing simultaneously in a single recirculating nutrient solution. In 1991, a study was conducted where trays of wheat (0.24 square meters per tray) at different stages, were grown simultaneously in the growth chamber. The study was conducted for 216 days, during which time 24 trays of wheat were consecutively planted (one every 9 days), 16 of which were grown to maturity and harvested. The remaining 8 trays were harvested on day 216.

Grain yields in this experiment averaged 520 grams per square meter, and had an average edible biomass of 32%. It was concluded that continual wheat production will work in this system over an extended period of time. What remains to be solved is how to avoid certain micronutrient deficiencies and toxicities.

An intriguing problem for plants in space is, which way is "down"? In 1989, corn plants circled the Earth for five days on the Atlantis Space Shuttle. On board the craft were 104 corn seeds, placed in aluminum canisters, which allowed air to enter, but admitted no light, so that the factor of gravity could be isolated for study. Simultaneous with the flight, 104 matching corn seeds were grown on Earth for comparison.

The scientists then analyzed specific growth hormones which they selected for comparison because they were known to be sensitive indicators of the plants' physiological status. They found that the hormones in the space-grown plants were



Trays of wheat, growing at different stages, in a plant growth experiment conducted by researchers at the Controlled Ecological Life Support System project at the Kennedy Space Center, Florida. Shown here are wheat plants grown hydroponically, at 6 days and 13 days of growth.

no different from those in control plants grown on Earth over the same time period. However, instead of growing straight "up," the corn seeds in space grew sideways.

Botanist Robert S. Burdanski, from Michigan State University, who designed the Atlantis corn experiment, observed, "Although the plants were physiologically the same, they looked quite different. The roots didn't know how to grow down, and the shoots tied themselves into knots because they didn't know where to go."

However, scientists foresee solving the problem by providing light to the plants to induce phototropism—growth oriented to the source of light—in the absence of geotropism, where growth is oriented by gravity.

One of the most recent successful experiments at the Kennedy Center CELSS Biomass Chamber is the production of potatoes. On Oct. 28, 1992, the third harvest of potatoes took place from an ongoing study. An abundant yield of 450 pounds of spuds came from hydroponic culture. The photograph on our cover shows the event, with NASA scientist Dr. Ray Wheeler (left) and Dr. Gary Stutte, a plant physiologist with NASA contractor Bionetics Corp. The researchers proceeded to analyze the nutritional value of the potatoes.

Once all the inputs required for plant growth (nutrients, water, temperatures, light) are supplied in the most optimal way known to researchers, how much light the plants can successfully absorb with which to conduct photosynthesis is a key determinant of high yields. In one study, wheat in a controlled environment showed average photosynthetic photon flux absorption of 90% during its life cycle, whereas a high-density field crop of corn showed only 50%.

Increase Earth's yields and productive area

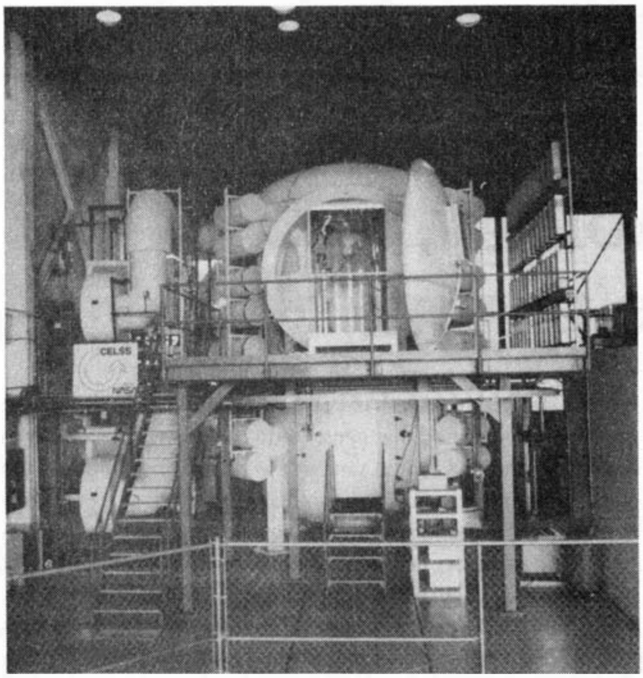
The results of some of the recent work on space farming can be enjoyed at an exhibit called the Land Pavilion, at Epcot Center in Orlando, Florida, which opened at Disney World in 1987.

Hydroponic fruits and vegetables are readily available commercially in Japan, and at some large-scale production locations in Europe, the United States, and elsewhere. In the best stores, you can "pick your own," without going outside, all year round.

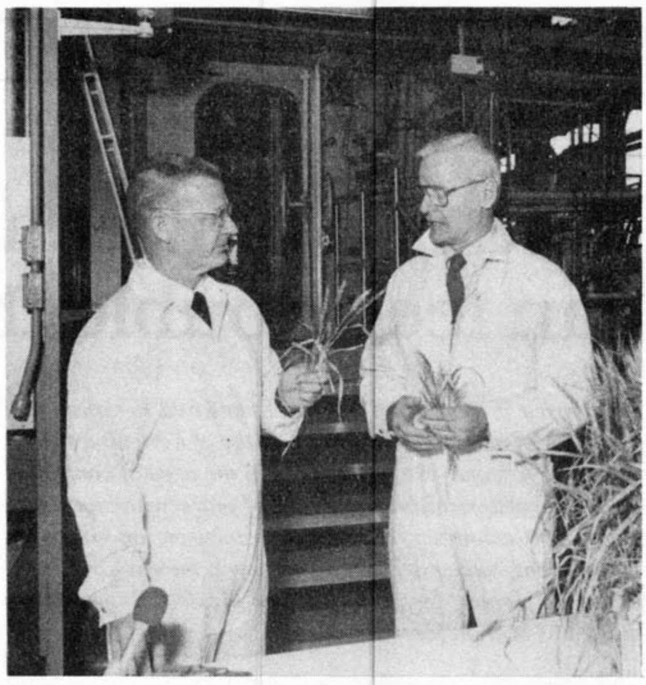
In addition, there is a thriving trade in CEA "kits" and apparatuses for the home gardener, or the enterprising individual trying to serve commercial or institutional needs. There are grow lamps, chambers, nutrient solution plumbing, and all manner of structural media for root support—such as rock wool, styrofoam, and baked clay granules.

In Mexico, the abundant volcanic rock has proved to be the perfect aggregate for supporting plants in successful hydroponic projects in Jalisco.

However, apart from these select few locations and initiatives, the widespread research and development and applica-



The Biomass Production Center of NASA's Controlled Ecological Life Support System (CELSS), at the John F. Kennedy Space Center in Cape Canaveral, Florida. In this module, plant scientists are experimenting on how to grow food under conditions feasible for supporting longterm human stay in space.



Kennedy Space Center Director Forrest S. McCartney (left) and Dr. Paul Buchanan, director of the KSC Biomedical Operations and Research Office, display dwarf wheat grown in the NASA Biomass Production Chamber. In these "sealed environment" experiments, scientists grew food using remote control devices and computer monitoring.

tion of the benefits of controlled environment agriculture have been held back for at least 30 years from places where this technology is most needed. Needless food shortages have been allowed to occur.

Consider briefly the overall world picture of agriculture land use and how little land has undergone infrastructure improvements to accommodate any form of "protected" cultivation, even timely water applications. Total estimated arable land worldwide was roughly calculated to be about 1.47 billion hectares in the mid-1980s, with about 1.38 billion hectares of that total under cultivation. Of the latter area, only about 219.7 million hectares was irrigated (16%). If irrigation had been extended to more of the world's existing arable cropland base in recent decades, then global food harvests would have increased, not stagnated and declined as they have done in recent years.

Beyond that, if other forms of controlled environment agriculture had been implemented, the Earth would be blessed with plentiful foods in all areas and for all cuisines.

In the United States, even the area under greenhouses used for food crop production (with or without hydroponics) has hardly grown. It was an estimated 233 hectares nationwide in 1973, and up to only 253 hectares in 1982.

One reflection of the lack of implementation of CEA is the demise of the Society of Soilless Agriculture and its *Journal*, which operated out of the Netherlands in the 1970s, but folded in the mid-1980s. The *Journal* had served as a much-needed international forum for the exchange of ideas about how to conduct protected agriculture systems in regions of adverse climate. Among the reports found in its pages were those about experiments such as how to hydroponically produce sheep fodder in arid South Africa.

By the 1990s, opposition to widespread CEA applications was coming from the quarter of the free-trade advocates. In 1992 in the United States, a 450-page report was issued by the Office of Technology Assessment to the 102nd Congress, titled *A New Technological Era for American Agriculture*. There is no mention in this study of the benefits of the spectrum of irrigated farming through to high-tech CEA. When, at the Capitol Hill press conference releasing the book, this author asked the spokesmen for the report why this was lacking, the reply was that food yield gains from irrigated and CEA farming were shown "as of the 1970s to be cost-ineffective." Instead, the report states that new "wonder foods" from genetic engineering are to be the focus of U.S. agriculture, in order to further competitiveness under the free-trade dogma.

In an upcoming *EIR* infrastructure study, we shall have more to say in refuting this free-trade myth. In this issue, we feature the views of one of the pioneers in the research and development of many forms of controlled environment agriculture, Dr. Merle H. Jensen.