In Space Agriculture, the Work of Carver Continues

Space agriculture. Not your everyday topic of conversation. Yet American, European, and Japanese scientists are conducting research on this topic. Why? Because 15 years or so from now there will probably be long-term manned space missions. People may be living in the Earth-orbiting space station to be built jointly by the United States, the European Space Agency, Canada, and Japan; they may eventually be inhabiting an outpost on the Moon or a base on Mars.

Is it feasible to take along enough food to last the duration of a mission lasting several years? Hardly. Is it feasible to continually resupply such a mission with food from Earth? No, again. So what is the alternative? To grow food in space: space agriculture.

The Life Sciences Division of the National Aeronautics and Space Administration (NASA) initially selected eight crops to be studied for growth in its controlled ecological life support systems (CELSS) program (see Chapter 47). These eight—wheat, rice, peanuts, soybeans, lettuce, sugar beets, white potatoes, and sweet potatoes—and the preparations derived from them could provide a balanced and varied diet for a space inhabitant.

by the Tuskegee University NASA/CELSS Sweet Potato Team (Walter Hill, Phil Loretan, Conrad Bonsi, Desmond Mortley, Carlton Morris, John Lu, Ralphenia Pace, Cyriacus Ogbuehi, P. K. Biswas, Jill Hill, Edwin Martinez, Esther Carlisle, Samuel Adeyeye, and Dana Greene), School of Agriculture and Home Economics, Tuskegee University, Tuskegee, AL

The Sweet Potato and Tuskegee

Some of the criteria for crop selection for CELSS were energy concentration, nutritional composition, ease of processing, proportion and yield of edible plant parts, storage stability, and flexibility of use. Sweet potatoes scored among the highest in all these criteria. Tuskegee University, in east central Alabama, one of the 1890 land-grant institutions celebrating their centennial, was asked by NASA to study the sweet potato.

Beginning with the pioneering work of George Washington Carver, who worked extensively with Alabama farmers on the sweet potato and developed 26 new food uses for it, Tuskegee University has a long history of research with this crop. USDA's Cooperative State Research Service has funded sweet potato research there for many years. In 1986, NASA provided funds to see if sweet potatoes could be grown hydroponically for CELSS. (Hydroponics refers to various technologies for growing plants with or without the physical support of an inert medium, rather than in soil.)

Tuskegee formed a team with diverse expertise in sweet potato research: Conrad Bonsi, plant breeder/pathologist; Walter Hill, soil chemist/plant nutritionist; Phil Loretan, engineer and sweet potato farmer; John Lu, food scientist; Ralphenia Pace, human

From left to right, food and nutritional science undergraduate Dana Greene, agricultural engineer Phil Loretan, plant pathologist Conrad Bonsi, project director Walter Hill, and food and nutritional science undergraduate Edwin Martinez are members of the Tuskegee University sweet potato team. The group examines hydroponically grown sweet potato crop suggested for use with NASA's controlled ecological life support system.

nutritionist; Jill Hill, computer systems analyst; P. K. Biswas, horticulturist/plant physiologist; and Carlton Morris, materials specialist.

The Science Story Begins

Initially, the Tuskegee team experimented with hydroponic systems using such media as sand, gravel, sawdust, perlite, and vermiculite, but these media posed potential problems given the mass and volume limitations of space cargo.

Within a year, the team decided to apply the nutrient film technique (NFT) to the sweet potato. This technique involves passing a thin film of nutrient-enriched water solution over the root system of the plants within the growing system, using no solid media. It had previously been used exclusively for aboveground crops. Tomatoes, lettuce, and cucumbers have long been grown commercially using NFT. Other scientists had tried to grow root crops, including the sweet potato, with NFT and aeroponic (nutrient spray) systems, but had obtained limited yields: good foliage but only small roots or none at all.

In their first attempt using NFT, the team used a commercial system. The result? A sweet potato resembling a carrot shaped like a long, coiled snake.

Walter Hill, Conrad Bonsi, and Phil Loretan had worked with the project in the greenhouse, and they remembered an experiment in which a plant grew with no medium. The plant was held above a nutrient solution by a grid resting on a pot. A small potato formed under that grid close to the side of the pot.

These three scientists, together with the team's materials specialist, Carlton Morris, came up with a design (recently patented) that so far has produced as much as 6.2 pounds (2.8 kilograms) of sweet potatoes per plant, with an average of 3.7 pounds (1.7 kilograms), using the variety of sweet potato known as TI-155, which was developed at Tuskegee. Georgia Jet, another sweet potato variety, bred at the Tifton, GA, Experiment Station, also produces well in NFT. The team's system is now consistently producing sweet potatoes.

"This has been a very efficiently run project," says Dr. William Knott of the Life Sciences Research Office at Kennedy Space Center in Florida. "The Tuskegee team has made enormous progress." Because of the system's success with sweet potatoes, comparative studies are being made with white potatoes and sugar beets.

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Long-term manned space missions will need basics such as food and air. Artist Pat Rowlings' view of a future lunar mining operation illustrates the production of liquid oxygen. Ilmenite, a fairly common oxygen-rich component of lunar soil, is shown being processed into liquid oxygen that will be used by the orbiting space station.

Questions To Be Answered

In space, plants will be grown in enclosed structures that will have to be protected from radiation and adapted to lower levels of gravity than on Earth —or no gravity at all—not to mention other complicating factors. Therefore, the effort of the second phase of research was to examine the effects of various environmental conditions on sweet potato growth.

To determine the exact needs of the structures, NASA asked specific questions: What is the best artificial lighting system, the best length of the light period, the best temperature, and the best humidity level for growing sweet potatoes? Would sweet potatoes grow if subjected to continuous light rather than the light/dark periods of Earth? How much light is optimum? If energy constraints limited the amount of light available, could sweet potato plants survive and still produce?

New researchers just beginning their scientific careers joined the team and conducted various experiments under greenhouse conditions and in environmental growth chambers. They included postdoctoral research associates Cyriacus Ogbuehi, Desmond Mortley, and Samuel Adeyeye; graduate research assistants Edwin Martinez and Dana Greene; and research technician Esther Carlisle. These young students of plant and soil science, food science, and biology brought tremendous energy and expertise to the team effort.

They conducted experiments to answer questions about the sweet potato's environmental needs, as well as other questions, such as the following: What cultural practices promote growth? How much space should there be between plants? Which varieties of sweet potato grow best in the system? What is the best nutrient solution for sweet potato production? When should it be applied, and should its composition change as the plants grow? What should the pH level of the solution be? Should it be constant or variable? What are the effects of continuous harvesting on sweet potato production in this system?

Sweet Potatoes in the Space Diet

The sweet potato plant has several unique aspects. One is that even a small section of the vines that are regularly produced can easily be cut off and used to start a new plant. Another is that it is a dual vegetable. The tender leaves that form near the vine tip make an excellent green vegetable. People in many African and Asian countries know this and eat them regularly.

Tuskegee food scientists John Lu and Ralphenia Pace have analyzed the hydroponically grown sweet potatoes with those grown conventionally in fields and have found that they compare favorably. As a carbohydrate, sweet potatoes are an excellent energy source; they also provide vitamin A.

The leaf tips are good supplemental sources of protein, iron, and calcium. Ralphenia has subjected the leaf tips to consumer studies and found sweet potato greens are acceptable to Americans. Dana Greene, with the help of a trained taste panel, is evaluating the acceptability of hydroponically grown sweet potatoes—including nonsweet, white-fleshed varieties. The energy and nutrition that come from this crop will be important to a space diet.

Space and Spinoffs

Tuskegee's research is linked to the Biomass Production Chamber (BPC) at the Kennedy Space Center, a three-story production facility that will test the chosen space crops individually and as they interact.

"The Tuskegee Project has already provided much of the baseline information needed for initial testing in the BPC," says Ralph Prince, agricultural engineer at Kennedy and technical monitor from NASA for the Tuskegee project. "Sweet potatoes are in the loop."

Although the main reason for the project relates to space, the research will provide useful information for farmers. Sweet potatoes are the seventh largest food crop in the world. Because it helps to quantify the environmental conditions needed for sweet potato growth, the team's system will serve not only the Nation's space needs but also those of sweet potato farmers here and around the globe. From the work at Tuskegee, scientists will be able to provide better information on how sweet potatoes grow best.

The National Space Program

Space agriculture needs to be put into the perspective of our Nation's space program. The 21st century will probably witness the first human footprint on Mars.

In 1986, the National Commission on Space recommended that the Nation "lead the exploration and development of the space frontier, advancing science, technology, and enterprise, and building institutions and systems that make accessible vast new resources and support human settlements beyond Earth orbit, from the highlands of the Moon to the plains of Mars."

The 1987 Ride Report focused on four possible initiatives in which the United States could maintain space leadership, initiatives that require ever-increasing technological capabilities: mission to planet Earth, exploration of the solar system, outpost on the Moon, and a mission to Mars. Our Nation faces a wide range of possibilities, and we will require advances in such areas as technology, life sciences/CELSS research, robotics, in-orbit assembly, and extraterrestrial systems.

It is difficult to grasp the amount and scope of the work facing the Nation's present and future space scientists and engineers—some of whom are not yet born or are in nursery or elementary school right now. Yet the work of science takes place one step at a time.

Space agriculture is at its threshold. The work at Tuskegee University with sweet potatoes and other food crops continues as an important segment of the NASA/CELSS program. With the team's research, the sweet potato research started by Carver moves into space.