Boost yields with new methods of agriculture

Fabulous plant yields are possible by use of energy-intensive agriculture in controlled environments. Non-soil-based methods include hydroponic systems, where the plants are grown in a liquid nutrient medium; and aeroponics, where the plant roots are in the open and periodically sprayed with a nutrient solution.

Variations of these non-soil-based technologies for use in space are sometimes called astroponics. Many improvements in technique have come about from scientists working on the problem of growing food in space, where the entire biosphere for plants will have to be created and controlled by man. NASA's research program into the controlled-environment life support systems is referred to as CELSS.

The accompanying table shows the comparative yields of wheat crops in controlled environments that were achieved by two NASA researchers in Utah, Frank B. Salisbury and Bruce G. Bugbee, in tests run during the 1980s. During one of their tests, they achieved the dramatic output of 4,760 grams per square meter of edible dry wheat biomass, in contrast to 500 grams per square meter, which is a good average yield for an open wheat field; or in contrast to the 1,053 to 1,450 grams per square meter achieved under other CELSS tests.

The results depend on the right combination of irradiance levels, number of hours of daylight, number of wheat plants per square meter, temperature, use of the right plant cultivar, ample water and carbon dioxide, and provision of all the basic elements that plants require, in the right relative quantities in a well-aerated nutrient solution. Under these conditions, a yield of about 50 grams per meter per day of wheat crop allows a "space farm" as small as 15 square meters per person.

High yields of wheat crops in controlled environments

Experiment	Days to harvest	Edible dry biomass g/m^2	Average growth rate (edible biomass) g/m^2/day
High average field	120	500	4.2
World record	140	1,450	10.4
CELSS:			
Soviet "Bios"*	60	1,314	21.9
Utah State University**	79	4,760	60.3

* Soviet simulated spaceship farm in Krasnoyarsk, Siberia
** Utah State University 1987 result by researchers Bugbee and Salisbury.
Source: *21st Century Science & Technology*, March-April, 1988.

Energy and water

CELSS research has found that light is the ultimate limiting factor for yield. Busbee and Salisbury reported in 1988, "Plants can't produce more chemical-bond energy in food than they absorb from the light that irradiates them—and, since they will never be 100% efficient, they will convert only some fraction of that absorbed energy to food." Their research shows that for maximum CELSS wheat yield, light input is required at an irradiance level of 2,000 micromoles/m^2/sec for a 20-hour period, for 79 days, with additional energy input required to maintain the crop plot at a 20°C/15°C day/night temperature.

Once the conditions are all met for the plant in question, Busbee and Salisbury stress that the "harvested end-products contain not only the mineral elements that were provided in the nutrient solutions, but also the carbohydrates, fats, proteins, and vitamins that are needed by the humans who will consume them. No plant grown in a rich, organic soil provides more nutrients required by humans than a plant grown hydroponically."

same number of households as the United States does, and Japan one-twenty-sixth. Thus, Germany's household density is 10 times that of the United States, and Japan's 26 times. We also saw that Japan consumes approximately one-half the kilowatt-hours per household the U.S. does, but 13 times more in per area terms. This takes us further.

There is an inverse relationship between the per household and per area ways of treating data, which is a function of population density. Higher population densities permit a concentration of per area resources which offset lower per capita supplies.

This points to the idiocy of those who look simply at the per capita values put into circulation by the international agencies, or anyone else, to say, for example, "Look how much better the U.S. is doing than either Japan or Germany. We have a much higher per capita energy consumption." The reality is more complicated. The United States has a higher per capita consumption, precisely because its land area has not been subject to the same depth of improvements effected in the case of Germany over more than 1,000 years. The per unit area measure is one reflection of the level of infrastructural improvement to the land, which permits more people to be supported per unit area, at comparable standards of living, for lower costs per physical unit of capital improvement.