Accelerating Into Tomorrow

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To maintain U.S. agriculture at a competitive and profitable level, productivity and production efficiency resulting from new knowledge and technology must continue to increase. In only 45 years, 1 farmer has gone from feeding 19 to 116 people by using better fertilizers and feeds, tractors, genetic hybrids, irrigation, and pesticides. Problems like soil erosion, aquifer depletion, and environmental pollution have occurred, but work on these problems is now leading to newer technologies like conservation tillage, learning to grow plants in weeds and stubble to minimize soil exposure; drip, surge, and other new approaches to irrigation; and integrated pest management using an increasing variety of available tools to manage crop and pest interactions.

There are many dramatic examples of increasing productivity in all agricultural areas. To illustrate only one, animal scientists in a recent comparison found that 33-pound pigs fed a 1907 diet gained 7 pounds in 60 days, while those on a 1983 diet gained 63 pounds, a ninefold increase in productivity.

Increasing productivity may mean even fewer farmers in the future. But it also means many exciting new careers in fields like biochemistry, agricultural engineering, plant and animal sciences (genetics, breeding, physiology and pathology), entomology, agricultural economics, and soil sciences.

The potential to increase productivity is, by no means, exhausted. Consider, for example, that the average yield for eight major U.S. crops—corn, wheat, soybeans, sorghum, oats, barley, potatoes, and sugar beets—is estimated to be only 20 percent of the record yield of the same crops. Of the unrealized 80 percent of the potential yield, stressful conditions (drought, salty soils, suboptimal temperatures, etc.) account for about 70 percent, with the remaining 10 percent attributable to insects and diseases. For all crops, record high yields are 3 to 7 times greater than their average yields.

And in the future, record yields too will be increased as plant physiologists understand phenomena such as the efficiency of basic nitrogen fixation, and water and nutrient uptake. A recent *Agricultural Research* article projected increases in yields of corn from an average of 113 bushels an acre today to 275 and 385 bushels an acre by the years 2000 and 2050, respectively. These yields exceed the highest experimental yields ever produced. New methods of growing, processing, and marketing will all be developed.

Future Tools

Computer science and biotechnology are two disciplines that will affect all areas of agriculture in the future.

Computer Science. Computers will be increasingly used to control operations and systems like pest management and irrigation with great precision. High cash crops will be grown in sophisticated greenhouses where computers will control 1) the root and shoot environments, 2) robots that seed, space, irrigate, manage pests of, fertilize, and harvest the plants, and 3) marketing selections for maximum profit. Tomorrow's tractors will be intelligent machines that use computers to plant, prune, selectively harvest, super cool and field

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Agricultural engineers find numerous and diverse applications for computers at The Land. On tomorrow's farms as well, computers are moving into areas like "expert systems" and robotics controls. Here, background plants grow hydroponically; soilless growing will find limited applications on earth but important applications in space agriculture.

pack crops automatically and with great precision.

Support for these kinds of developments will come from agricultural engineers like Roy Harrel at the University of Florida, who has already developed a prototype robot to harvest citrus.

Biotechnology. Horticulturists and foresters are already using one area of biotechnology called tissue culture to clone huge numbers of disease-free vegetables, ornamentals, and forest trees starting with tiny plant parts and sometimes even single cells.

In doing genetic engineering, molecular biologists who introduce new genes into plant cells also depend on whole plant regeneration to see expression of that gene. In one example, plant genetic engineers succeeded in transferring the structural gene from the major storage protein in bean seeds into tobacco plantlets, where it did produce the bean seed protein at low but constant levels.

Animal scientists are excited by experimental results with bovine growth hormone produced industrially by genetically engineered bacteria. The hormone can increase milk production by 10 to 33 percent without proportionately increasing feed intake, at least on a short-term basis.

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Horticulturist uses tissue culture for rapid propagation and production of disease-free clones.

Genetic Diversity

Today less than 0.1 percent of about 350,000 available plant species are used for agriculture. Agronomists, particularly plant breeders and geneticists, are extremely concerned about preserving and, in some cases, cataloging this invaluable future resource. Genes to incorporate traits like disease resistance and salt tolerance into tomorrow's crop plants will come from this vast germplasm pool. Similarly, continued improvement of animal agriculture is dependent on preserving and using world resources of animal germplasm.

Some plants will be selected from this germplasm pool for cropping in the future, for new uses or products, and to meet the need for crops that are adapted to adverse environments. Two examples for potential food use are 1) winged bean for the wet tropics with high protein seeds, leaves and pods for vegetables, and starchy tuberous roots, and 2) buffalo gourd for the deserts with seeds high in vegetable oil and protein, and starchy roots.

Green plants, the best solar-energy-capturing devices known, produced today's gas, oil and coal deposits, and will help meet tomorrow's hydrocar-

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Little-known plants like Euphorbia lathyris *may be important future sources of hydrocarbons, industrial raw materials, and biochemicals for medicine.*

bon needs. Jojoba seeds are 50 percent oil of such high quality that this desert shrub will help save the sperm whale by replacing whale oil for special lubricating applications. You'll also hear about another desert shrub called guayule for domestic natural rubber production, and plants like *Euphorbia lathyris* and *Copaifera multijuga* for mobile fuels. The latter, a Brazilian tree, can be tapped to yield 40 liters of a material like diesel fuel annually.

New Frontiers

Agriculture will move into space on orbiting stations and lunar and planetary bases during the 21st century. Green plants will be required for food, landscaping, and to help recycle carbon dioxide, nitrogen, and water. Although soil scientists may find that extraterrestrial soils support plant growth, much space horticulture will be through hydroponics or soilless growing where 13 normally soil-derived essential plant elements are dissolved in the irrigation water. Horticulturists, entomologists, and plant pathologists are anxious to learn how their particular organisms will behave and interact in the microgravity of space.

Exciting Careers

The past 85 years alone have given us hundreds of new tools like tractors, controlled-atmosphere storages,

pest-controlling chemicals, computers, center-pivot irrigation systems, and plant breeding. Our knowledge base in all fields including plant and animal biology has increased exponentially.

Since producing food, fiber, wood, fuel, environmental beauty, and other agricultural products must continue to be the most important technology over the next 85 years as well, the future looks incredibly bright and exciting for all agricultural disciplines. Today's best students will be needed to apply the continually expanding base of science and technology to applications in agricultural engineering, agronomy, animal science, forestry, food technology, and other fields to continue both solving agricultural problems and increasing productivity.

The Land

Future World at Epcot Center is a place where the technologies, tools, and concepts for tomorrow are displayed for the millions of guests visiting the Walt Disney World Vacation Resort annually.

At The Land, sponsored by Kraft, 30 young agricultural professionals grow the most important and potentially important world crops in the environments of a tropics, desert, production greenhouse, and creative farm. Horticulturists and agronomists like Margit Hentschel (University of Florida 1984) produce tons of cucumbers, tomatoes, lettuce, bananas, malabar, peppers, and other crops for Epcot Center restaurants in controlled environments using hydroponics.

They're supported by 4 entomologists like Chris Halliday (Penn State 1981), and 3 plant pathologists like Jean Batzer (University of Minnesota 1982), who are developing a highly effective integrated pest management program emphasizing biological controls. The young scientists work with sophisticated tools in growth chambers, laboratories, and greenhouses, learning to use agricultural pests' natural enemies for their control.

Andrea Grainger (Auburn University 1985) and Tom Ardelt (Illinois State University 1986) are animal scientists producing fish for Epcot Center's restaurants in the densely populated raceways in The Land's aquacell. For conservation, water is recirculated through an elaborate filtration system. In addition to studying this state-of-the-art aquacultural facility, Andrea and Tom are also evaluating new animals, cropping systems, and feeds.

Agricultural engineers provide essential support to all production and research efforts at The Land.

Eldon Muller (University of Idaho 1981) heads up the computer team, working on projects like detailed environmental monitoring of all growing areas, crop scheduling and pest prediction modeling, and precision computer-control of operations like crop irrigation and aquacell flow rate. He writes software as well as evaluates new hardware as it becomes available. On the horizon—robotics!!

Other specialists, like Sandra Gerdes (University of Iowa 1981) who propagates The Land's pineapples, bananas, strawberries and other clones via tissue culture, round out The Land team, a team approaching the Future World of agriculture with excited anticipation.