Agricultural Research

Role of Research in Agriculture

Orville G. Bentley, *Assistant Secretary for Science and Education*

Several factors have been involved in establishing the productive capacity of U.S. agriculture, and high on the list are research and technological innovations. Past investments in research have produced hybrid crop and animal strains, labor-saving equipment, improved cultural practices, animal disease control, and availability of chemicals to enhance growth and protect plants from pests. The use of these technologies has resulted in a higher standard of living for both consumers and producers. A wide variety of wholesome food can be purchased at lower relative prices than at any time in the past, and most farm families enjoy a level of living that was not available to earlier generations.

Despite past successes in productivity gains and industry well-being, global economic changes of the past 5 years have resulted in a considerable decrease in demand for U.S. exports. These developments have had a reverberating impact on rural America resulting in a considerable reduction in land values and financial hardship for many farmers and ranchers. Recent changes in macro-level influences, however, suggest that future opportunities should be brighter:

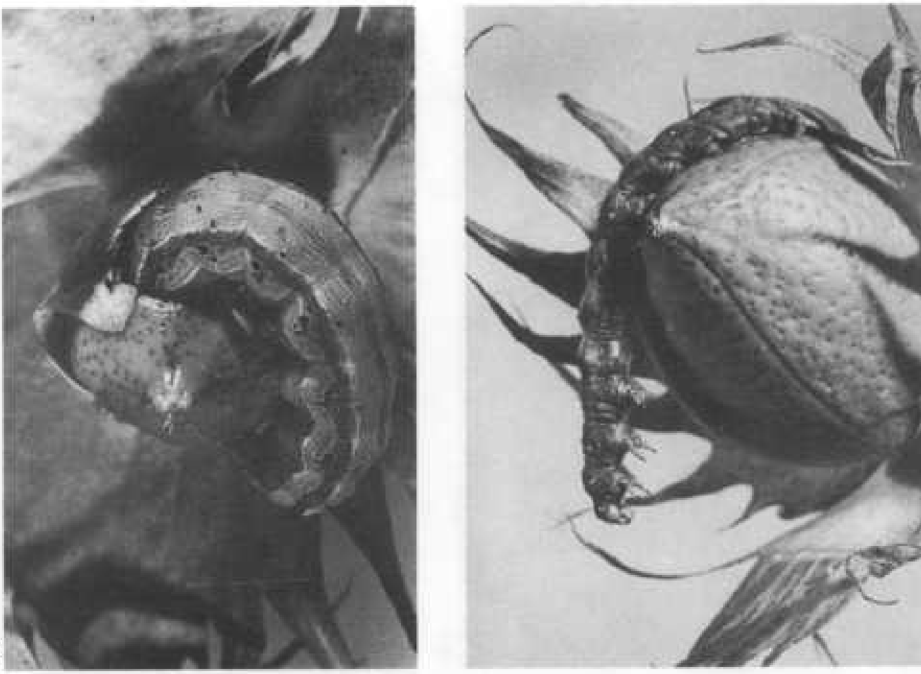
- In recent months the value of the dollar has declined 20 to 30 percent as compared to other currencies. This change reduces the costs of U.S. goods in foreign markets.
- Intense negotiations are under way with our trading partners to encourage exchange of goods on a more level playing field.
- Interest rates and energy costs have come down, easing two of the major expenses of modern-day agriculture.

These positive trends should improve the competitive position of U.S. agriculture. But changes in the rest of the world's ability to produce agriculture products will challenge U.S. access to global markets. In January 1986, Dennis T. Avery, senior analyst with the U.S. Department of State, reported: "annual world production of grain and oilseeds has jumped by 213 million tons in the last four years, while world consumption has increased only 153 million tons. The largest share of the increase in crop output has been in the Third World. Better farm technology, due to increasing human knowledge and broader world communication, has been the single most important factor in this progress." Technology that allowed the United States to develop a productive agricultural industry is now being adopted much quicker by other countries.

What unique strengths does the United States possess to compete effectively in domestic and foreign markets—remaining a net exporter of food and fiber, rather than an importer? Two important strengths are: 1) A strong commitment to the role of science in our national well-being and 2) an entrepreneurial spirit—freedom of economic oppportunity to explore new markets.

The future role of research in agriculture was outlined effectively by Vernon M. Ruttan in an editorial in *Science*, February 21, 1986:

> The capacity of American agriculture to expand its foreign markets and retain its domestic markets depends on continued declines in the



Left: A cotton bollworm eats its way into an unprotected cotton boll. Right: Overcome by a viral insecticide, a cotton bollworm hangs from the boll of a viral-protected cotton plant. At the slightest touch the caterpillar will rupture to release billions of virus particles that could spread to protect other plants.

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real costs of production. American agriculture has achieved its preeminence in the world by substituting knowledge for resources. This knowledge, embodied in more productive biological, chemical, and mechanical technologies and the managerial skills of farm operators, has given the United States a world-class agricultural industry at a time when many other sectors of our economy are losing their preeminent position. A necessary condition for U.S. agriculture to retain its status is enhancement of both public and private sector capacity for scientific research and technology development. The costs, to both consumers and producers, of failure to maintain and enhance our efficiency in production would greatly exceed the adjustment costs resulting from abundance.

Beginnings of Agricultural Research

Agricultural experimentation took place in the first permanent English settlements in what is now the United States. The first settlers at Jamestown and Plymouth learned, with Indian aid, to grow corn. In 1613, John Rolfe of Jamestown experimented with Orinoco tobacco and developed our first export crop. The leaders of a settlement in Georgia in 1733 not only established an experimental garden, but hired a botanist to collect plants in the West Indies and Central and South America. During the 18th century, other efforts, in-


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Samuel W. Johnson, 1830–1909, America's first advocate of agricultural research. His efforts led to the establishment in 1876 of the Connecticut Agricultural Experiment Station—first in the United States.

spired in part by the agricultural revolution under way in England, were made to improve agriculture.

George Washington created a veritable experimental farm at Mount Vernon. He worked to conserve his soil and diversify his crops, and pioneered in using new machinery. He was America's first mule breeder and greatly improved his sheep.

President Washington made the first formal proposal for the establishment of a Federal Agency devoted to agriculture, Later, the president of Norwich University asked Congress to appropriate funds from land sales to be distributed to the States for establishing institutions to teach agriculture. During the 1840's and 1850's State legislatures, farm leaders, the editors of agricultural periodicals, farm organizations, and professional and philanthropic societies, urged Congress to act on both of these proposals.

In 1839, Congress appropriated $1,000 of Patent Office funds for collecting agricultural statistics, conducting agricultural investigations, and distributing seeds. Opposing groups said this action was inadequate and represented Federal intervention. The matter was settled on May 15, 1862, when Abraham Lincoln signed into law legislation creating the U.S. Department of Agriculture (USDA). The Act was part of an agrarian reform package offered to the voters by the Republican party.

The Morrill Act of 1862 was the foundation legislation for the land-grant colleges. The primary focus of this Act was not research but to provide the common man with an opportunity for higher education. But the emphatic assignment of a teaching mission seemed to overshadow any research authority and prompted the first generation of college administrators to doubt that the Act authorized the colleges to experiment, except as an aid in the instruction of students.

At the 1871 Convention of Agricultural Editors, University of Illinois President John M. Gregory called attention to the seemingly incidental role the Morrill Act had allotted to research. In an urgent tone, Gregory noted the need for a well-developed system of research had become a serious practical question. Farmers, faced with problems they could not solve, were bringing to the college staff questions that could be answered by astute, continuous, and productive experimentation.

After considerable discussion in the press and at public meetings about State versus Federal responsibilities, the science and education leaders of the time convinced Congress of the need for Federal funding of agricultural research. The result of all this discussion was the Hatch Act of 1887 which celebrates its 100th anniversary in 1987.

The purpose of the Hatch Act was to establish agricultural experiment stations in connection with the land-grant colleges authorized in 1862. These experiment stations were to conduct scientific investigations and experiments that would provide practical and useful information. The Act specifically mentioned original research and verified experiments. Research topics included physiology of plants and animals, diseases of plants and animals, crop rotation advantages, chemical composition of plants at different stages of growth, analysis of soil and water, chemical composition of manures, digestibility of different kinds of foods for animals, and scientific and economic questions about the production of butter and cheese. The 1887 Act also indicated the need for publishing bulletins or reports of progress.

A second Morrill Act was passed in 1890 specifically to support the predominantly black land-grant institutions. These 16 institutions, plus Tuskegee University, are called the 1890 institutions. Subsequently, the Adams Act (1906) and Purnell Act (1925) provided for additional Federal investment in State experiment station research.

The post-World War I depression in agriculture, surplus production, and the migration of rural people to urban areas led to a realization that research to generate new production technology was not adequate by itself. Economic and sociological investigations also were needed. These were provided for by the Purnell legislation.

In 1914, the Smith-Lever Act authorized USDA to provide, through the land-grant colleges, instruction and practical demonstrations to help people identify and solve their farm, home, and community problems.


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John M. Gregory, 1822–1898, first regent of Illinois Industrial University (now the University of Illinois) and eminent leader in agricultural education.

In 1935, the Bankhead-Jones Act increased suppport for research, extension, and teaching activities. It also required Federal funds to be allocated to each station in relation to the relative importance of the rural population of the State and required the State to match the Federal funds received to support research. In 1946, the Act was amended to provide for research to improve and facilitate the marketing and distribution of agricultural products.

In 1962, the McIntire-Stennis Act recognized the scientific and technological needs in the Nation's forests. It authorized cooperative forestry research between USDA and State universities. The 25th anniversary of this legislation is 1987.

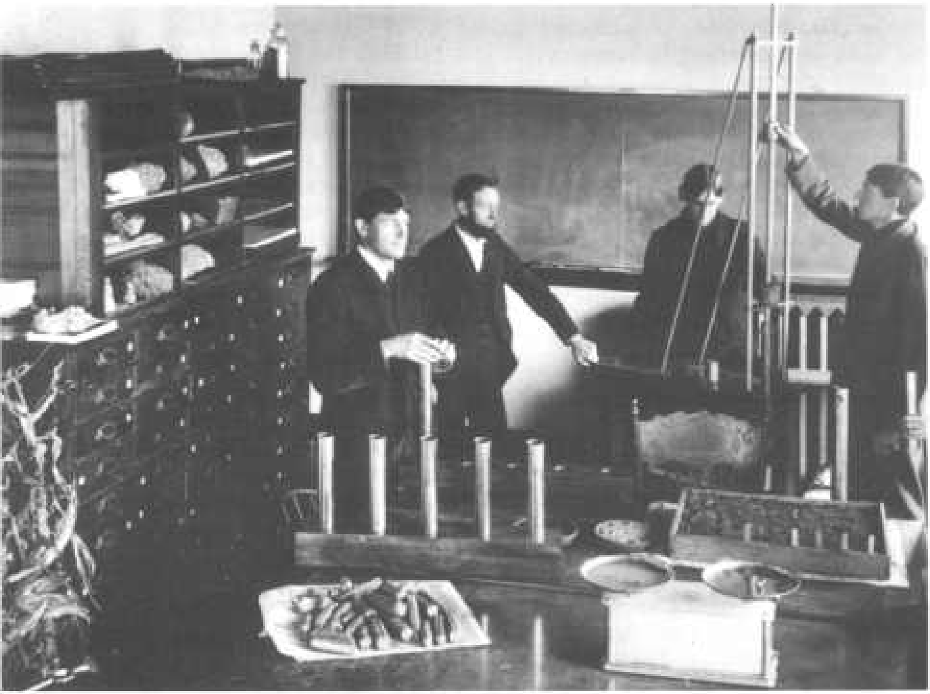
Performers of Food and Agricultural Research

The United States is fortunate to have a unique system of agricultural research and education that has proven its ability to respond quickly and effectively to society's needs. It is a three-faceted system consisting of higher education, research, and extension of knowledge to the public. One of its strengths is its diversity.

The higher education system includes community colleges, land-grant universities, other public universities and colleges, and privately financed institutions of higher education in every State.

Research related to agricultural production and marketing is conducted by the 56 State Agricultural Experiment Stations including departments of forestry, colleges of veterinary medicine, and home economics; by 16 separate schools of forestry, Tuskegee University and sixteen 1890 colleges. Federal funds for these facilities are channelled through USDA's Cooperative State Research Service. The main internal performers of research in USDA are the Agricultural Research Service, Forest Service, and Economic Research Service. The Office of International Cooperation and Development has the responsibility for coordinating the Department's international science programs. In addition, there is considerable research and development activity occurring in the private sector.

Research findings are transmitted to ultimate users by an Extension education system unique to the United States. Organization of this Extension system begins at the county level, making it truly a "grass roots" organization. Cooperative Extension has staff located in nearly every county nationwide. Extension has programs



Students study agronomy at the University of Rhode Island Agricultural Experiment Station in 1902.

for farmers and ranchers to demonstrate new and improved production and marketing technology; seminars on innovative marketing techniques for agribusiness and producer cooperatives; and even courses emphasizing basic nutritional needs for homemakers and families.

In addition there are programs in resource management, energy conservation, and health and safety, as well as those designed to help 4-H Club youth develop leadership skills and explore careers and other developmental activities; demonstrate to homeowners lawn and garden care, the use of pesticides and herbicides, and ornamental horticulture; and assist community groups and local officials in analyzing needs and resources for community development.

Recent Legislative Developments

The passage of the National Agricultural Research, Extension, and Teaching Policy Act in 1977, amended in 1981, resulted in significant management and program changes. This Act firmly established the USDA as the lead Federal agency for food and agricultural sciences. Before this Act, agencies conducting federally supported research were established at different times in response to different needs, and their work was not fully coordinated. Further, it established an assistant secretary of agriculture for Science and Education to carry out the responsibilities of the Act.

To provide for better cooperation and coordination in the performance of agricultural research by Federal departments and agencies, State Agricultural Experiment Stations, colleges and universities, and user groups—two advisory bodies were authorized.

The National Agricultural Research and Extension Users Advisory Board was established to incorporate the views of users. It makes annual recommendations on budgets, program priorities, and agency operations.

The Joint Council on Food and Agricultural Sciences was established to provide better cooperation and coordination among Federal and State interests. Its most important activities have been reported in four document—Needs Assessment, 5-Year Plan, Priorities Report, and Accomplishments Report—that are being used extensively by legislators, administrators, and scientists.

The top five national priorities selected for special emphasis by the Joint Council in 1987 were: 1) Agricultural profitability issues; 2) water quality and management; 3) biotechnology research on plants, animals, and microbes; 4) scientific and professional human capital development; and 5) human nutrition and diet and health relationships.

The long (20 years) and mid-term (5 years) needs and objectives are addressed in the Needs Assessment and 5-Year Plan. The accomplishments report highlights the annual results of these research and education activities.

Congress recognized that the food and agricultural sciences needed extra effort in the basic sciences to achieve breakthroughs in knowledge that could support innovative food and agricultural technologies. The 1977 Act, as amended in 1981, established a program of grants for high-priority agricultural research to be awarded on the basis of competition among scientific research workers at universities, Federal agencies, private organizations, and individuals not associated with any institution. The Competitive Research Grants Office was established to implement this legislation. It adopted most of the same procedures used by the National Science Foundation. Also, a program of education grants and fellowships was established to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Computers monitor physiological and behavior reactions to milking and other functions of the animal.

strengthen training and research programs in the food and agricultural sciences.

The 1985 Food Security Act reiterated the importance of research to the economic viability of U.S. agriculture. Some highlights in the act include: an expanded research and development program on new uses for farm and forest products; development of appropriate controls for biotechnology research and its products; dietary assessment; and increased effort in helping financially depressed farmers.

Future Agricultural Problems

Great and exciting opportunities lie ahead. A core of excellent scientists are using cutting-edge scientific techniques to resolve agricultural problems. Examples of the major problems and the challenges they offer follow.

New Scientific Tools. Improvements in modern computer systems and the development of biotechnology have created exciting opportunities in agricultural research. The technology for gathering, analyzing, and disseminating information is advancing rapidly. Modern computer technology and telecommunications offer great potential for increasing agricultural productivity by improving efficiency of information exchange between and among scientists, Extension specialists, producers, and consumers. Electronic mail will enable scientists to make daily contact with colleagues throughout the world who are working in the same research area.

Because of the discovery of the chemical structure of the genetic code of life some 30 years ago and the development of gene-splicing techniques in the past 10 years:

- living organisms can be harnessed for the production of large quantities of specific biological products;
- sexual reproduction can be bypassed in the transfer of specific desired traits between plants, animals, and micro-organisms; and
- DNA, that master molecule of heredity, can now be studied close up in ways not imagined only a few years ago.

These new abilities, along with other advances in such areas as microculture, cell fusion, and regeneration of plants from single cells are creating vast new opportunities all across the agricultural sciences.

Assuring the Security of Renewable Resources. Despite scientifically and technologically enhanced production capacity and the current surplus of food, uncontrollable climatic conditions could rapidly eliminate food reserves and cause food shortages. This underscores the irony that scientifically sophisticated agriculture is still at nature's mercy. The decisive factor in assuring the security of our renewable resources will be the abilities of our farm people and technological progress.

To assure food security, production systems must be developed that are more sophisticated and efficient with better control of weeds, diseases, and pests and less dependent on weather. Transportation systems will be developed to move raw agricultural commodities and finished products to consumers more efficiently. New technologies in processing and packaging will insure the continued availability of a low-cost, year-round food supply. Storage technology will allow storing new varieties of commodities and controlling insects and bacteria that have become increasingly resistant to current control methods.

Because of changing political and economic circumstances worldwide, the Nation is giving increased attention to assuring domestic production of needed agricultural industrial materials, as well as food and fiber, wherever it might be economically and technologically feasible. Research has shown that plants can supply numerous industrial raw materials, such as fats, oils, waxes, and natural rubber used in enormous quantities by industry. Of the 14 crops that have been identified and can be grown domestically, two will be discussed here.

Crambe, a member of the mustard family of Mediterranean origin, has a seed oil containing 55–60 percent erucic acid and could replace all imported rapeseed oil. Derivatives of erucic acid are used to make plastic sheets of film slip one over another without sticking; as a fixative for perfumes and fragrances; in nylons for use in manufacturing molded and extruded items such as gears, fasteners, and tubing and coatings, adhesives, films, and fibers.

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To increase the amount of rubber in guayule plants, a chemist sprays them with bioregulators.

Guayule is a drought-resistant shrub which grows wild in semiarid regions of North America. In the early 1900's, guayule provided 10 percent of the world's natural rubber supply. After World War II, the plant was abandoned in favor of synthetic rubber. Recent improvements in agronomic and processing technologies suggest that it may once again be a competitive source of natural rubber. Natural rubber is preferred for certain applications such as bus, truck, and airplane tires; fan belts; surgical rubber; and hydraulic hoses. In addition, having a domestic source of natural rubber is an important security issue.

Assuring Protection of Nonrenewable Resources. Average Americans often take their relationship to the natural environment for granted. The importance in absolute terms of the environmental resources, however, grows steadily with each passing year. There is great concern about the adequacy of the U.S. natural resource base to sustain continued expansion of agricultural and forestry production.

The farmer of the future will concentrate heavily on the efficiency of resource use, reducing production costs as a means of improving profitability. Many technologies will be needed to enhance crop yields and reduce their variability from year to year. Water management and conservation technologies such as drip or trickle irrigation and surge-flow irrigation will produce water savings over conventional practices. Laser leveling of land will prepare it for more effective water usage. Infrared guns will measure plant temperatures and indicate water stress. Field conditions will be monitored by sensors and tied in with weather satellite forecasts to aid irrigation scheduling. Our limited energy resources will be used more efficiently. Introducing nitrogen-fixing capabilities into nonleguminous plants will dramatically reduce the cost of using nitrogen fertilizer and ease the pressure on natural resources. Air quality will be improved to prevent atmospheric deposition which affects crop yields, tree growth, lake ecology, and fish and wildlife habitats.

Enhancing International Competitiveness. "The two most important elements of a national research strategy for the United States are (1) education and (2) mechanisms for bringing scientific discoveries from the laboratory to the marketplace. The application and development of scientific innovations in this country have traditionally been a source of unique strength. Today, this is an area that requires material improvement if we are to retain our commanding lead in international technological competition."

This statement by John Diebold in the Spring 1986 *Issues in Science and Technology* is a truism of immense importance. In the past, agriculture has been cited as the outstanding example of transferring scientific knowledge into useful applications. This past success will not automatically continue into the future unless the science and education system in agriculture adjusts to changing conditions. For example, an improved understanding of changing foreign and domestic markets is needed.

Enhancing World Peace and Supporting Foreign Policy. The United States has a long and enviable record of sharing its resources and knowledge with other countries in a continuing effort to promote economic stability, reduce poverty, and solve world food problems. U.S. agriculture has the basic ingredients to assure a role of leadership in this international arena. It has a strong and viable agricultural science system; a solid and proven research, Extension, and teaching system; an effective partnership with the private sector; policies that articulate and emphasize scientific cooperation; and experience in a wide range of international cooperative activities. Exchanging knowledge and training programs provides a foundation for better training partnerships and a better understanding by the peoples of one country of the needs and customs of peoples of another. It can go a long way toward supporting foreign policy and enhancing world peace.

Improving the Quality and Safety of Food and Fiber. Through research, the United States will develop agriculture products that are more appealing to consumers and more nutritious. Not only will techniques be developed that will detect the smallest amounts of agricultural, industrial, or natural toxicants in foods, but production techniques will assure these harmful substances do not get in our food.

Improving Human Nutrition, Health, and Well-Being. Americans have access to more high-quality, moderately priced, safe and nutritious food products, than any other people in the world. The metabolic relationship between nutrient intake and physiological response needs to be better understood. Adequate nutrition and proper dietary practices will reduce the risk of various diseases such as cardiac disease, diabetes, and some forms of cancer. A better understanding of the needs of pregnant and lactating mothers and newborn infants will reduce infant disabilities and mortality. We will have a better knowledge of the relationships between nutrient quality and human genetic potential and will have the ability to alter naturally occurring food ingredients via biotechnology. The opportunities are limitless.

Need for Trained People. The new opportunities in science require trained people. Many agricultural scientists received their formal education 20 to 30 years ago and are reaching retirement age. Areas of importance are molecular biology, systems analysis, and international marketing. These shortages were highlighted at a conference held in 1984 on "Brainpower for Agriculture"—cosponsored by USDA and the National Academy of Sciences. In addition to a continuing funding problem in higher education, the traditional images of agricultural fields need modification so that talented students will more objectively evaluate career opportunities in the agricultural sciences.

Jonathan Baldwin Turner—Evangelist of the Land-Grant University Movement

Patricia B. Lewis, *public information consultant, New Jersey Agricultural Experiment Station, New Brunswick*

With the livid language, sonorous prose, and grand manner of 19th century oratory, Jonathan Baldwin Turner devoted his life to the idea of general, practical education for the masses.

Turner was an evangelist of ideas in the three areas that consumed him—religion, politics, and education. In all three, his views were unorthodox and brought him severe criticism and some personal abuse. Still he would not modify his stands, and finally it was the melding of religious fervor with political skill that allowed Turner's educational philosophy to become the law of the land.

Ideas developed by Turner spread far beyond Illinois where he honed them and came to encompass the entire United States through the land-grant university movement. With the missionary fervor of a John the Baptist, Jonathan Turner never missed an opportunity to advance his ideas. He fought relentlessly for education for the sons and daughters of the working class; an education "suited to their aptitudes, interests and careers."