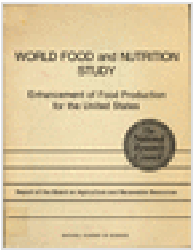

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WORLD FOOD AND NUTRITION STUDY

Enhancement of Food Production for the United States

A Report of the

Board on Agriculture and Renewable Resources
Commission on Natural Resources
National Research Council

prepared for the

NRC Study on World Food and Nutrition

NATIONAL ACADEMY OF SCIENCES
Washington, D.C. 1975

NOTICE

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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NATIONAL ACADEMY OF SCIENCES

OFFICE OF THE PRESIDENT
2101 CONSTITUTION AVENUE
WASHINGTON, D C 20418

November 10, 1975

The President
The White House
Washington, D. C.

My dear Mr. President:

In December 1974 you wrote "to enlist the aid of the National Academy of Sciences in a major effort to lessen the grim prospect that future generations of peoples around the world will be confronted with chronic shortages of food and with the debilitating effects of malnutrition." You requested that, "...in cooperation with the Department of Agriculture and other governmental agencies you (the National Academy of Sciences) make an assessment of this problem and develop specific recommendations on how our research and development capabilities can best be applied to meeting this major challenge."

This request was most welcome. Indeed, the Academy, together with the National Science Foundation, had already begun to address these questions. In September 1975, under our joint auspices, an overview was provided in a report entitled Population and Food: Crucial Issues, prepared by a committee chaired by Dr. Daniel G. Aldrich, Jr. of the University of California at Irvine.

The terms of reference of the new undertaking were established in discussions with an inter-agency committee; a contract signed in June 1975 between the National Academy of Sciences and the National Science Foundation provided the supporting funds for a study by our National Research Council, the report of which is to be submitted within two years. We also agreed to provide in November 1975 an interim report to assist government agencies in the formulation of their programs for FY 1977. At this time I am pleased to transmit that report which consists of two essentially independent documents.

Last year, in a report entitled Agricultural Production Efficiency, prepared by a committee of the Board on Agriculture and Renewable Resources of our National Research Council, attention was directed to the limitations now affecting further increase in American agricultural production. Already well versed in these problems and aware that, for the foreseeable future, the world will need and welcome all the food that the United States can produce, BARR, chaired by Professor Sylvan Wittwer of Michigan State University, was in excellent position to prepare Enhancement of Food Production for the United States. This thorough report provides detailed findings and recommendations concerning research priorities for improving and increasing food production by American agriculture, thereby enlarging the world's food supply.

To elucidate the nature and magnitude of research expressly designed to assist in coping with world food and nutrition problems, as you requested, there was brought into being a Steering Committee chaired by Professor Harrison Brown of the California Institute of Technology, and administratively based in the Commission on International Relations of the National Research Council. Their work to date, addressed to this large and complex challenge, is summarized in Interim Report: World Food and Nutrition Study. This report identifies areas of research deemed to be of particularly high priority for immediate expansion and support and suggests some organizational steps that would make the research efforts more effective. In this case, emphasis is given to that research, wherever conducted, which, if successful, could enhance food production in the developing countries themselves. Finally, this statement also describes the scope of concerns to be addressed in the final report of the Committee.

Attached to this Interim Report is a special statement on Recommended Actions on Nutrition Research and Development which was prepared by a committee chaired by Professor Hamish Munro of Massachusetts Institute of Technology, under the auspices of the Food and Nutrition Board of the Assembly of Life Sciences of the National Research Council. This report, prepared for consideration by the Steering Committee, is here presented so that it may receive wider attention.

The cooperation and assistance of various federal agencies concerned with food and nutrition in the early stages of preparing this interim response to your request of last December were most helpful. We look forward to their continuing cooperation as well as to submission of a final report of this study in June 1977.

Respectfully yours,

P Handler

Philip Handler
President

PREFACE

This report on Enhancement of Food Production for the United States is a product of the Board on Agriculture and Renewable Resources (BARR) which provided the leadership and coordination for the study. BARR is a board of the Commission on Natural Resources of the National Research Council (NRC). There were contributions from other NRC units. The recommendations presented here are based upon consideration of research and development needs that were assembled at workshops by informed professionals from government agencies, academia, private industry, philanthropic foundations, and international agricultural research centers. These recommendations reflect a belief that the world food problem is both immense and urgent, and that understanding of it is still evolving. It is further believed that the process of gaining, disseminating, and applying relevant new knowledge by individuals functioning in the agricultural systems of the U.S. and of the world is our best hope for the future.

Sylvan H. Wittwer
Chairman
Board on Agriculture and
Renewable Resources

ACKNOWLEDGMENTS

The Board on Agriculture and Renewable Resources wishes to express its appreciation to all those who, in addition to the Board members themselves, contributed to this report either through providing input to the manuscript or reviewing parts of it. Their names are listed on the following pages. The Board gratefully acknowledges their contributions without implying that the contributors necessarily subscribe to the content of the report, including its recommendations.

We are also grateful to Selma Baron, Joyce Dawson, Michele Moore, and Joan Spade of the Board staff, and to Walli McCoy, Estelle Miller, Vikky Jones, and other staff members of the Commission on Natural Resources for their various tireless efforts in preparation of the manuscript.

Philip Ross
Executive Secretary
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PART ONE

CHAPTER 1

INTRODUCTION

On December 3, 1974, President Ford addressed a letter to the President of the National Academy of Sciences and a memorandum to the Secretary of Agriculture calling for an assessment of the food problem. He requested recommendations for a program of research and development to insure the food supply and improve the nutrition of our country and that of all nations. He asked that priorities be set, specific programs outlined, and needed resources determined.

Partial resolution of food and nutrition problems around the world will come from both the enhancement of production in agriculturally developing nations and the improvement of the agricultural system in the U.S. The focus of this report, however, is primarily upon the improvement of U.S. food producing capabilities. Thus, it is a partial response to the President's request. A subsequent report will address the issue of other nations.

This report on *Enhancement of Food Production for the United States* consists of two parts. In Part One, the Conclusions and Recommendations point up some gross deficiencies in our current investments in agricultural and food research and give specific suggestions for replenishing the scientific pool of knowledge that has been drawn upon heavily during the last two decades without being adequately maintained (NAS 1975a). Recommendations are provided on management of technological innovations in food systems, and constraints on U.S. agricultural production and research are discussed along with suggestions for improving the ways the science research activities of a wide range of U.S. institutions concerned with food are observed, reported, and managed.

Part Two stresses the U.S. needs for an assessment of land, water, and manpower resources, and for research concerning human nutrition, energy, weather, crop and livestock protection, fertilizer, the production of crops and livestock, and biological processes that control or limit productivity. The discussion emphasizes development of new technologies in food science and human nutrition.

The attempt to treat these subjects adequately with so little time and manpower has been a formidable undertaking. It has been necessary to limit the scope of inquiry to the technological (biological, physical, and chemical) research and development needed to enhance production of food, improve the dependability of food supplies, conserve resources, and improve nutritional intake. This limited scope, however, reflects a realistic view of capabilities, not a denial of the important interrelationships between the production and distribution of food and other phenomena and issues.

Ultimately, starvation and malnutrition can only be alleviated by achieving a balance between world population and food production. In the short term, there is little this country can do to alter the population side of the earth's population-food equation. Some experts feel that the number of people in the world will almost double in the next 25 years. It is virtually inevitable that by the end of the century world population will total 5.8 billion as a minimum. Reduction in the world's gross birth rate will be partly offset by decreasing mortality. However, the decline in the birth rate itself will be retarded by the number of prospective child-bearing females in the current population who were produced by recent high birth rates. There will be a large number of young parents in the developing countries for another 50 years or so. Housing, clothing, and food for several billion more people will be required, worldwide, even if the average number of children per newly-formed family falls immediately to two.

In recent years, many assessments and projections of the world food situation have been made, and priorities for food and nutrition research have been suggested, both in the U.S. and elsewhere. The World Food Conference, held in Rome on November 5-16, 1974, and sponsored by the United Nations, provided one of the major assessments. Some of the other major efforts which have been of great assistance in preparing this report are summarized in the selected references that follow this chapter. The NAS (1975b) has published a study on _Population and Food: Crucial Issues_ in which the general features of the problems are described. In addition, a workshop sponsored by the Agriculture Development Council, convened in April 1975, yielded reports on the transfer of agricultural technology to less developed countries. The Food and Agriculture Organization of the United Nations (FAO) produces periodic reports. Studies by the National Research Council (NRC) are underway on "Renewable Resources for Industrial Materials," "Climate and Weather Fluctuations and Agricultural Production," and "Food Science and Technology Needs."

Symposia sponsored by professional societies have been scheduled such as _Maximizing Agricultural Productivity_ and _Food, Population, and the Environment_. Entire issues of scientific journals have recently been devoted to food production. There are frequent editorials concerned with food problems. Documents on food are available prepared under contracts between individuals and government agencies. Numerous congressional hearings on food and agriculture have been held. A national working conference on _Research to_

Meet U.S. and World Food Needs sponsored by the USDA-State Universities-Industry was held in Kansas City, Missouri, July 9 to 11, 1975, at which research needs were rated by a balloting system. The Michigan Agricultural Experiment Station and the Charles F. Kettering Foundation, with the financial support of USDA, U.S. Agency for International Development (USAID), National Science Foundation (NSF), and Energy Research and Development Administration (ERDA), sponsored an International Symposium on Crop Productivity, October 20 to 24, 1975. The Massachusetts Institute of Technology, with the cooperative efforts of industry, university, and government experts and the support of the NSF, has assessed Protein Resources and Technology: Status and Research Needs.

These many reports, documents, and activities, as well as others, have been considered and used as background for the recommendations that follow. We recognize that research described in these recommendations and strategies is already in progress. Furthermore, there is a substantial body of information already at hand that would go far toward enhancement of food production if it were mobilized and delivered through appropriate channels and put to use by various government and private agencies.

The issue of more effective science management suggested by the notion of "organizational prerequisites" for effective research deserves particular emphasis. Significant increases in funding for innovative and crucial research programs should follow from the recommendations of this report. Such increases, however, will be dissipated if certain critical managerial and organizational problems are not addressed and resolved. Archives are filled with documents, including those from the NRC, that give recommendations for future research, yet even the results of past research have not always been effectively implemented. Without change in the degree of coordination within and between the federal agencies involved in research on food, we would not expect a sharpened efficiency in the overall food research system. New investments in research and development are needed, but they should be accompanied by changes in the administrative procedures and resource management practices of the concerned agencies. A high priority should be assigned to making efficient use of new findings.

Research strategy of the past, in line with the admonition of Jonathan Swift in Gulliver's Travels, was to grow two ears of corn where one grew before. Enhancement of productivity should still rank first among research priorities, but there are now other important--and not always complementary--objectives. Increased production must now be sought with the lowest possible inputs of nonrenewable resources of land, water, energy, and fertilizer, and with achievable minimum environmental impacts.

Stability of yield at high levels for the major food crops should become a national goal. It is essential that the relationship between production enhancement on the one hand and production dependability on the other be recognized in future planning. While the two are not necessarily mutually exclusive, they can become so if long-term dependability is sacrificed to short-term productivity.

Constraints on agricultural production in the U.S. make apparent the need for research on socioeconomic factors. Although some reference is made to the desirability of studies of the socioeconomic implications of many of the recommendations in this report, its focus is on biological, physical, and chemical research needs. This restriction is recognized. It does not imply that the other concerns should receive low priority, or that the U.S. research establishment is not capable of responding to them.

The report describes innovative approaches, promising quick benefits, that could be initiated now. However, other programs are considered that require long and continued effort that should also be started without delay. Specific recommendations directly relevant to these needs are given. This report represents the best collective judgment of a large array of scientists and research administrators drawn from government, academia, foundations, and industry. It is our hope that it will be of immediate usefulness to federal and state agencies and private institutions for assessing goals and setting priorities in agricultural, food, and nutrition research.

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CHAPTER 2

CONCLUSIONS AND RECOMMENDATIONS

The immediate purpose of this report is the identification of technologies which, if implemented in the U.S., could have an impact on meeting the food needs of a growing world population and the demands of increasingly affluent societies.

There are at least three major reasons other than humanitarian ones why we should increase food production in the U.S. First, people worldwide are restless: there is increasing violence and struggles for freedom. Food must be provided along with education and health care. Second, it is in the best interest of American business to increase food production. Expanding exports of agricultural commodities are the only real hope for maintaining a balance of payments in international trade. Third, increased food production is in the best interest of the American consumer. If production is not increased, food prices will continue to rise even faster than they have during the past two years.

The rapid increase in world population adds its own urgency to the U.S. need to increase food production. Nevertheless, were the present rate of expansion in population to be maintained, it would, in due course, nullify all efforts to decrease hunger and malnutrition in the world. An additional 25 million tons of grain must be produced each year to feed the current annual increment in world population. The research and development efforts recommended in this report are vital to gain time--until the expansion of population comes at least partially under control. No other course accords with both the long-term self interest and the humanitarian tradition of the U.S. Our recommendations must be considered in the context of a situation made desperate by the large annual growth in human population.

The recommendations that follow emphasize the technological (biological, physical, and chemical) research and development needed to enhance production and improve the dependability of U.S. food supplies, conserve resources, and improve nutrition. Fully developed recommendations concerning institutional, economic, and social changes required to increase domestic production are not provided.

There is an urgent need for establishing national goals and policies in food and nutrition research including an improved institutional framework for reporting, observing, and managing the wide range of U.S. research activities related to food. A more coherent overview and annual assessment of the national food and nutrition research by the 15 or more federal agencies, the State Agricultural Experiment Stations (SAES), and industry is needed to identify priorities and integrate effectively the activities of public and private research programs. Non-agricultural interests (such as the environment and rural development) as well as agricultural interests should be reflected in this annual assessment. General recommendations on the need for funds for agricultural, food, and nutritional research, by public and private institutions, should be developed.

We suggest that a National Agricultural Research Policy Council representing the many federal and state agencies responsible for agricultural and agriculturally related research be established. It should have responsibility for establishing national agricultural policies and goals. (See Chapter 3.)

We further suggest that science and technology be assigned a prominent role within the structure of the U.S. Department of Agriculture, and that research be emphasized as a major mission. (See Chapter 3.)

Included in this negotiation is the appointment of a principal scientist and spokesman for agricultural research and one concerned with science and technology, equipped with staff and budgetary support that would make the USDA the focal point for food related research.

More site-specific, mission-oriented, applied research is needed in the U.S. to produce technologies to increase the production of food and enhance the dependability of its supply over the next two decades. Over the long interval, increased understanding of the biological principles underlying agricultural productivity will be the source of the major contributions. Both short- and long-range research have been substantially reduced over the past decade because the buying power of appropriations and grants has fallen far behind rising costs.

We recommend a substantial increase of support for research directed toward the production, dependability, and quality of the food supply. (This recommendation is supported throughout the report.)

Financial support for such research should be increased to restore at least the 1966 buying power, and the support should be broadly distributed.

State and federal support--now totalling about $450 million per year--for research related to agricultural productivity should be increased immediately by 40 percent. This would restore the buying power of the 1960s. The 40 percent increase could be effectively used by current staff and facilities of the USDA and the SAES, and by U.S. universities with support from food-related programs sponsored by NSF, NIH, and AEC-ERDA.

Methods for funding applied research should be flexible, permitting financing of both the unique thrusts of the individual scientist and the relatively massive concentration of resources required in multidisciplinary programs focusing on major, complex agricultural problems.

Biological research related to food production has benefitted enormously from the diversity of goals and kinds of support provided by NSF, NIH, AEC-ERDA, and the USDA-SAES programs. NSF has, in general, supported research fundamental to all living things. NIH has supported research with general relevance to medicine and human health. AEC-ERDA has supported programs related to energy, radiation, and nutritional up-take. The USDA and SAES have emphasized site-specific, mission- and commodity-oriented applied technologies. All these approaches are required, and their progress and efficacy should be enhanced by additional funding that will maintain the current balance of the system.

We believe that responsibility for administration of the bulk of regular appropriations should remain vested in the USDA-SAES complex. However, we further recommend that a competitive grants program be initiated and administered by the USDA and other agencies to encourage research in critical areas identified in the report. (See Chapter 3.)

Interaction among those working in the basic scientific disciplines, U.S. agricultural research institutions, the international agricultural research centers, and programs in agriculturally developing countries should be encouraged in the grant program.

There is a need to facilitate the movement of new technologies and information to food production sites. (See Chapter 4.)

More effective distribution of scientific and technical information concerning agriculture could have a significant impact on food production. Much of the information contained in scientific reports is usually not written in language understandable by its most important potential user, i.e., the farmer. Other information possessed by the practitioners themselves is not adequately shared.

State-of-the-art reports and farm management bulletins in specific areas should be issued. Socioeconomic inputs must also be considered in such publications, each of which would present in a clear and idiomatic way an analysis of what is known and what requires further local or regional research. It is important to make special efforts to reach each cultural group. Audiovisual aids should be developed for those who cannot read.

The U.S. cooperative extension organizations responsible for technology delivery systems--now including production, nutrition, policy, rural development, related to the USDA-SAES--should be broadened to make effective use of the technology and information of other federal and state agencies engaged in agricultural, food, and nutrition research. An example could be a weather advisory system, including seasonal and longer-term forecasts, to provide weather information for more effective management of food producing systems.

The federal plan which has been partially implemented by NOAA for improved weather information services should be expanded to include national coverage. (See Chapter 10.)

Agricultural management systems are sensitive to weather. Investments in machinery are determined by the climate of an area and day-to-day decisions by farmers require correct interpretation of short-range weather outlooks. Accurate, short-range biological forecasts based on the accumulation of past weather studies determine the design and operation of emerging pest management systems. The effectiveness of hydrologic systems for handling feed lot wastes, the availability of solar energy for grain drying, and the design and operation of water management systems all profit from accurate short-range weather forecasts. Changing climate and fluctuating weather add further complications to farming and fisheries.

We recommend that U.S. professional educational needs with respect to the technological aspects of food production be identified. (See Chapter 13.)

Existing programs need to be strengthened and new ones established. Training programs supported by USDA, NSF, NIH, and USAID as well as state funds are needed for those who will conduct the nation's food research in the future. While national undergraduate enrollments are up in colleges of agriculture, well-focused, food production oriented, graduate training programs need stimulatory action both to increase their output and to better tune them for the challenges ahead. In addition, many educational programs in the applied agricultural (both biophysical and social) sciences are separate from the biological, chemical, and social science departments in institutions of higher learning. The separating of basic and applied research is so sharply drawn as to exclude concern for food production-oriented basic research.

Programs for training of young U.S. scientists and retraining of established investigators must be instituted to bring the quality of science that undergirds agricultural productivity to a higher level. Thus, along with the general additions to existing programs in colleges of agriculture there must ultimately be university affiliated laboratories dedicated to specific programs of agricultural productivity and to the training and retraining of agricultural scientists in the most modern and effective methodologies of the physical sciences.

Training is needed in basic research on the biological processes that control or limit crop, livestock, and fish productivity; on the biology and ecology of rhizobial technology and pest management; and on the biological and behavioral sciences that underlie human nutrition, food science and technology, environmental science, and waste management. Animal health scientists are critically few:

most veterinarians treat pets and do not address the needs of livestock, poultry, and fish production industries. Expanded training programs should channel substantially more resources toward solving problems of food production, animal health, and infertility. The problems are multidisciplinary; they cannot be handled with technology alone. Further, there is a need for a new generation of plant scientists trained in the fundamentals of physiology, biochemistry, genetics, and ecology and better trained in the techniques of modern physics and chemistry.

Though this report deals mainly with biological and physical research to enhance food production and improve stability of supply, the overview called for must include research on institutional, social, and economic aspects of the food problem.

We, therefore, recommend that concerned agencies and organizations mount an effort to appraise research contributions from the social sciences appropriate to the solution of problems involving food production.

SPECIFIC RESEARCH RECOMMENDATIONS

The specific technical research recommendations which follow focus on crop and livestock production and on the dependability of our food supply, the resources that are necessary to achieve that productivity and dependability, and the requisite processing and storage technologies and distribution systems necessary to insure that food will reach those in need. The recommendations concern the principal areas of research needed to meet short- and long-term food requirements.

Fundamental research undergirding food production technology has languished for two decades. The NSF has not focused on agriculturally related research, although it has given substantial support to botany, zoology, and plant and animal physiology and pathology. The USDA-SAES complex has not adequately funded basic research relating to biological processes that control crop and livestock productivity and insure a greater stability of supply.

Because of crop surpluses, political pressures from commodity groups, budgetary reductions, and emphasis on immediately applicable results, a formerly substantial basic research effort in the Agricultural Research Service (ARS) and the SAES virtually disappeared. Consequently the agricultural research system now faces inadequacies in fundamental knowledge about photosynthesis, nitrogen fixation, crop and livestock protection, water and nutrient efficiencies, genetics, biochemical aspects of handling and processing of crops, livestock and fish, and plant-soil-water relationships.

The first three of the specific recommendations which are considered high-priority research areas will require coordinated massive efforts.

Specific Recommendation I

(See Chapter 14)

Expand research on photosynthesis so as, ultimately, to increase crop productivity through:

(a) an increase in carbon dioxide assimilation by modulation of the flow of carbon during photosynthesis;

(b) an increase in net photosynthesis by regulation of the wasteful processes of dark respiration and light-induced respiration;

(c) redistribution of carbon within the plant to increase the agronomic yield; and

(d) adaptation of crops to utilize full seasonal potential by control of flowering and senescence.

Basic research on photosynthesis is urgently needed to determine how the regulatory properties of the enzymes of carbon metabolism relate to the flow of carbon. This approach could lead to an increase in the rate of carbon dioxide uptake and to a diminution of wasteful respiratory losses that could result in a substantial increase in productivity of some crop plants.

The agronomic yield or harvest index is a measure of how the products of photosynthesis are partitioned between seed and non-seed parts of the plant. Improving the distribution of carbon within the plant is an urgent goal of plant physiologists and breeders especially as net photosynthesis is improved. A large research effort is required to understand the mechanisms underlying the translocation of carbon within the plant.

In many geographical regions there are enormous wastes of the photosynthetic system because the crops grown are poorly adapted to the local temperature and day-length patterns. Crop varieties should be chosen or developed (i.e., through control of flowering and senescence) which can use the full potential of the growing conditions by retaining their maximum rate of photosynthesis. Planting schedules can be designed for optimum capture of solar energy.

The current level of funding for all research on photosynthesis in the U.S. is approximately $10 million and widely dispersed among 75 to 100 federal, university, and industrial laboratories throughout the nation. The current investment base for photosynthesis is primarily derived from NSF ($4 million), NIH ($1 million), AEC-ERDA ($2 million), and SAES ($3 million). A twofold increase from the several federal agencies enumerated below is recommended for fiscal 1977 to be distributed as follows:

(a) Two or three federally funded, university affiliated national institutes with a central theme of research on photosynthesis should be established at land-grant universities or other universities with strength in this area. Close cooperation of plant physiologists, plant biochemists, agronomists, and physical scientists is a prerequisite to better understanding and ultimate mastery of this complex biological process. Support from the NSF on the order of an additional $4 million annually is urgently recommended for these institutes which would also become the focal points of research training.

(b) Additional funds should be made available to the NSF, NIH, and AEC-ERDA extramural grants program and to the Experiment Station Program, to allow an approximate 50 percent increase in their current support of research on photosynthesis.

(c) A competitive USDA grant program should be undertaken with special emphasis upon photosynthesis and the regulation of photosynthetic rates in crop plants. An initial investment of $1 million is recommended.

Specific Recommendation II
(See Chapter 15)

Strengthen research on biological nitrogen fixation, with particular emphasis on improving understanding of the biological and chemical processes involved, and on identification of nitrogen fixing systems applicable to major economic species of cereal crops and forage grasses.

Establish a publicly supported Center on Nitrogen Fixation Technology to acquire, evaluate, maintain, and make available to research workers a comprehensive collection of nitrogen-fixing microorganisms. Train technologists in this field. Provide a mechanism for monitoring inoculant quality.

Fertilizer nitrogen has become increasingly expensive, and fossil fuel for its manufacture and transport will continue to become more scarce. Yet, over the last 20 years scientific and technical skills in biological nitrogen fixation and the supply of experts in nitrogen fixation microbiology have not increased substantially.

There is now an urgent need to establish research and extension teams in various climatic regions where efforts of microbiologists, plant breeders, geneticists, plant and microbial physiologists, plant nutritionists, biochemists, agronomists, and agricultural extension specialists can establish coordinated programs for developing and field demonstrating increased biological nitrogen fixation.

Additional multidisciplinary research teams of 10 to 12 scientists at those institutions with strength in the area should investigate the chemical and biochemical mechanisms as a basis for discovery of new chemical methods for nitrogen fixation. Other teams are needed for studies of the genetics of nitrogen fixing organisms so that the nitrogen-fixing capability can be transferred from one organism to another. Research should focus on ways of decreasing dependence upon chemically synthesized nitrogen fertilizer, and on increasing the supply of biologically fixed nitrogen by forage and grain legumes and nitrogen-fixing associations of microorganisms with grasses, shrubs, trees, lichens, and marine organisms, and the design of new cropping systems.

A technology center is needed to acquire, evaluate, and monitor the quality of inoculants sold to farmers. Such a center would also train technologists for a nitrogen-fixing field training program and produce professionals in the genetics of nitrogen fixing microorganisms and general rhizobial microbiology.

The current funding level of less than $5 million from all sources in this nation for research on biological nitrogen fixation is grossly inadequate. Research funding should be increased to $25 million beginning in fiscal 1977, with a 25 percent annual increment of the base for the next 5 years.

Specific Recommendation III

(See Chapter 16)

Develop techniques for genetic manipulation beyond those of conventional plant breeding, including in vitro techniques for asexual approaches, and broad-crosses between crop species.

Programs to improve varieties will continue to make major contributions to crop production. Exploratory research on single cell culture and somatic cell genetics suggests that, using these methods, it may be possible to propagate and to improve a wide variety of otherwise genetically incompatible cultivars. Furthermore, the transfer of genetic information between species and genera of plants, or between bacteria and higher plants, though previously impossible by normal sexual methods, may be achievable by DNA recombination techniques. The potential for improved crop production and quality with these new genetic techniques is great. (See the references to Section II.)

Photosynthesis and nitrogen fixation are interdependent processes, and research on one is complementary to the other; more carbon flow is essential if biological nitrogen fixation is to be enhanced. Moreover, since new techniques for genetic manipulation have worldwide application in the development of new and improved plants, research in all three areas should be coordinated.

Less than $500 thousand is currently invested in non-conventional plant breeding in the U.S. It is recommended that research funds be increased fivefold beginning with a doubling in fiscal 1977.

Some of the payoffs for increased research investments in photosynthesis, biological nitrogen fixation, and non-conventional plant breeding could occur within five years; others would require ten to twenty years. The scale of the potential payoffs could be equivalent to the returns from the discovery of hybrid vigor and the more accurate use of chemical fertilizers.

The 1975 MIT report on "Protein Resources and Technology: Status and Research Needs" supports these recommendations.

Specific Recommendation IV
(See Chapter 9)

Improve technologies for abiotic nitrogen fixation as alternatives to the present reliance on natural gas for chemical fixation. Develop improved catalytic procedures with low energy requirements for production of fertilizer nitrogen. Improve efficiency of use of fertilizer nitrogen by crops.

Increasing amounts of fertilizer nitrogen have been a significant factor in increasing grain production. TVA estimates that in 1972 the total world use of nitrogen was 33.7 million tons, and that by 1980 total use will be between 53 and 61 million tons. Energy shortages, environmental constraints, transport limitations, and costs dictate the need to discover and develop improved technologies for production of fertilizer nitrogen.

The current recovery of less than 50 percent of nitrogen, phosphorus, and potassium applied to crops mandates a research investment to improve efficiency of uptake.

It is recommended that an additional $25 million be made available to develop technologies of abiotic nitrogen fixation through the pilot plant stage. An additional $1.5 million per year for 3 years will be required to improve nitrogen uptake by crops.

Specific Recommendation V
(See Chapters 7 and 8)

Complete an inventory of the land resources of the United States and support the 1975 Assessment of Water and Related Land Resources effort of the U.S. Water Resources Council.

Food production capacity and stability of yield are dependent upon land and water resources. The information and reporting system, here as well as abroad, is inadequate. Estimates of the reserve land resources for crop production in the U.S. alone vary from 20 to 60 million hectares.

High priority should be given to completing a detailed soil mapping survey of the U.S. Such information is needed to identify land and water most suitable for potential food production. It is required in order to designate what currently tilled land is suitable for preservation and protection. Such information would also provide a rationale for land and water use decisions.

A first approximation for the U.S. could be completed in 3 to 5 years through the use of modern technology, such as the "Land Sat" programs and computers.

Water is available both as a mined, nonrenewable resource and as a renewable but limited resource. Under rapidly increasing demands from agriculture and other segments of society, we must optimize use of water resources. Agriculture suffers from some degree of water deficiency over the entire globe. In some instances, nonrenewable water resources are being mined for temporarily circumscribed agricultural production. It is thus mandatory that we have an inventory of water resources for establishing policies on future use, and for estimating sustainable agricultural production capacities. Drought is one of the major factors producing food shortages. Future dependability of food supplies requires the preservation and protection of water resources and improved management technologies.

Specific Recommendation VI
(See Chapter 12)

Design a concerted program of research in pest control to improve existing techniques and develop innovations for crops and livestock and for food products.

Pests (insects, weeds, viruses, bacteria, fungi, nematodes, vertebrates) are competitors with man for food and fiber. One-third of the annual harvest is destroyed by pests, and substantial losses due to pests during storage further reduce the productivity of U.S. agriculture. Many pests are also vectors of pathogens of disease in plants, livestock, fish, and humans.

Encouraging developments in several areas suggest that intensified research on new pest control technologies can have a significant effect on food production. In particular, attention should be focused on the development of research programs on (1) biologically-based hormone or pheromone analogues that interfere selectively with the reproductive process of the pest species; (2) microbial and natural biological agents for pest control, especially the bacculoviruses; and (3) integrated approaches to pest management, embodying ecologically-based strategies based on combinations of the above methods with cultural, genetic, and conventional chemical techniques.

If these measures could be translated into applications, they would achieve significant and highly visible increases in yield in a short time. They are also necessary to forestall the developing impact of genetic resistance in pest populations to chemical pesticides, and the decreased availability of these compounds arising from shortages of petrochemical feedstocks or environmental constraints on their use.

We endorse the recommendations of the NAS report, Pest Control: An Assessment of Present and Alternative Technologies (NAS, in press).

Specific Recommendation VII

(See Chapter 11)

Evaluate alternative technologies for reducing the energy used in producing agricultural commodities, and in assembling, distributing, and utilizing foods and feeds.

The U.S. food system (production, processing, distribution, preparation) uses 12 to 15 percent of the total energy consumed nationally, of which only about 3 percent is used in the production phase. Opportunities exist for applying specific technological practices for reducing energy inputs into agricultural production while at the same time conserving land and water (by such means as no plowing, slow release fertilizers, or crop rotations).

Alternative pathways for production, processing, and distribution and food preparation for each major food commodity should be reviewed, and an assessment including economics made of comparable fossil fuel energy inputs. New technologies should be examined as opportunities to reduce energy use at each phase of food producing systems.

The current investment base for energy research in U.S. agricultural food producing systems approximates $1 million. A fivefold increase for fiscal year 1977 is recommended.

This additional funding should be invested in an examination of existing alternative technologies. Regional efforts through the SAES should be funded. In addition, a competitive grant program should be expanded to support this activity.

Specific Recommendation VIII
(See Chapters 18 and 19)

Increase production of domestic food animals, poultry, and fish by improving fertility and reducing disease.

The food producing function of domestic animals is to convert to meat, milk, and eggs the nutrients from crops, forages, and by-products that do not have greater value in other uses. Food producing animals that are residual bidders after food-crop and industrial crop requirements have been satisfied, should receive priority attention. As a renewable resource, our livestock must be produced from the existing populations. Replacement of the animals slaughtered is least expensive and most efficient from a minimum number in the reproducing population. High reproductive performance and maximum disease control is achieved by reducing embryo and fetal mortality and death of the young.

U.S. research on animal health should deal with diseases current not only in America, but elsewhere. This would enhance the supply of animal protein while preventing the introduction of diseases into American animal populations, including diseases to which humans are susceptible.

Approximately $10 million is currently invested in research in the U.S. for the reduction of infertility in livestock. This investment should be doubled and funded as a competitive grant program administered by the Cooperative State Research Service of the USDA. The program should support innovative research with contracts of 3 to 5 years. Additional funding is needed for disease control research.

Specific Recommendation IX
(See Chapter 17)

Develop and use effectively forage systems and rangelands for domestic food animals.

Forages and rangelands provide more than half the nutrients consumed by livestock and beef and dairy cattle. Sixty-five to seventy-five percent of the feed units come from forages. Because of increased use of feed grains for human consumption and increased costs of grains for livestock, feeds must come from high quality forages and by-products. Beef and dairy cattle alone produce more than half the nutrients consumed by Americans, but production will be decreased unless alternative sources of nutrients are provided for livestock. A major research effort is needed to improve forage yields, increase the nutritional value of forages, and increase the efficiency of forage use by animals.

The total current research expenditure on forage crops, pastures, and rangelands is $30 million annually spent by publicly supported state and federal laboratories in the U.S. Because of the complex nature of the research needed in all states and on more than 50 crop species, this research effort should be increased to $60 million annually. New federal funds administered by the USDA should be provided to state and federal laboratories that are currently engaged in pasture, forage, and grassland research.

Specific Recommendation X
(See Chapter 21)

Improve the technological and scientific basis for aquaculture.

The potential for increased food production through aquaculture is large if appropriate research effort is applied. Areas where urgent research is needed include the following: (1) methods of increasing supplies of seed (eggs and larvae) through studies on reproductive physiology to induce maturation and spawning in captivity and the development and maintenance of brood stocks; (2) genetic modification and selective breeding; (3) nutrition of cultured animals and the development of inexpensive and nutritionally effective feeds; and (4) disease prevention and control.

The current annual funding of research and development of aquaculture in the U.S. approximates $22 million of which $12 million is from the federal government, $2 million from state sources, and $8 million from industry. Among the nine federal agencies in five departments, the Fish and Wildlife Service (Department of the Interior), NOAA, and the Office of Sea Grant (both Department of Commerce) are the most active. They spend, respectively, $4.4, $2.4, and $3.8 million annually. A level of funding at 50 percent above the present level ($33 million) is suggested for expansion of food production through aquaculture.

CHAPTER 3

OPERATIONAL STRATEGIES FOR SCIENCE IN U.S. AGRICULTURE

INTRODUCTION

The U.S. agricultural research system is a composite of many federal, state, and private institutions and organizations operating under a variety of institutional, social, political, and profit structures and incentives. The major thrust of food-concerned research is conducted by various federal agencies and SAES through programs associated with the USDA. However, food-related research is also conducted or sponsored by numerous colleges and universities, state agencies, a broad segment of private industry, and by at least 15 major divisions of the U.S. Government. (Divisions of the U.S. Government conducting or sponsoring food-related research are: Department of Agriculture; Department of the Interior; Department of Health, Education and Welfare; Department of Defense; Department of Commerce; Agency for International Development of the State Department; National Science Foundation; Energy Research and Development Administration; National Oceanic and Atmospheric Administration; National Aeronautics and Space Administration; Tennessee Valley Authority; Department of Transportation; Department of Housing and Urban Development; Environmental Protection Agency; National Bureau of Standards; and Federal Trade Commission. Also, see the Report on the Federal R&D Program FY 1976, Federal Council for Science and Technology, National Science Foundation, February 1975, for a discussion of the principal food research activities in the federal establishment.)

The success of the agricultural industry in this country indicates the relative effectiveness with which the separate components of the agricultural research system have responded to the needs of the agricultural and food industry. These separate components operating collectively have arrived at approximately correct decisions through a complex of incentives that help the components determine what research should be done, when, and by whom. This interaction of the diverse components of the research system has developed over time as an adaptive response to the lack of any central means of support review and coordination.

The nature of this interrelationship among agencies and their administrative structures is important because it is through this interaction that the research system selects the mix of research and at the same time minimizes costly duplication, overlap, or inefficiencies.

Among the many factors contributing to an effective and efficient research system are the review and planning of research programs in relation to problems needing solutions and to the fulfillment of national and regional goals, the allocation of resources to insure attention of researchers to important goals and problems, and the support of these by an administrative structure that can relate and coordinate the diverse research system into units responsive to the agricultural and food needs of the country.

Any overt action designed to affect the food production and delivery system through the research system requires the manipulation of this complex set of factors in such a way as to enhance and certainly not to interfere with the productivity of the system. To accomplish this without explicitly directing the individual institutions and organizations of the agriculture research system--to lend direction to but not direct research--is the function of the management of science and the agricultural research management system.

In considering the issues associated with managing science in U. S. agriculture, there is a basic presumption that any consideration for making recommendations for improvement must be based on the existing agricultural research system.

The recommendations in this section of the report reflect a view of the study committee. The agricultural research system is no longer considered to be supporting a particular "way of life" in this country. It is supporting a complex system of processes which provides the foundation for the very existence of future generations in this nation and the world. The changes the committee proposes in the U.S. agricultural research management system underscore the belief that it is time to recognize agriculture as a national resource and to treat it as such.

A NATIONAL AGRICULTURAL RESEARCH POLICY COUNCIL

A National Agricultural Research Policy Council should be established to provide representation from, communication with, and consideration of the total agricultural research system in devising national policies and strategies for strengthening agricultural research.

A number of events have indicated both a need and a desire for the kind of central focusing of research efforts that could be provided by a national strategy for agricultural research. The federal-state research system has been developing a structure to bring about a degree of national focus on research planning. Both Houses of Congress have introduced bills aimed at encouraging some centralization in research planning.

These and other planning efforts do contribute to improving the effectiveness of research selection and management. However, the efforts devised to date generally fall short of supplying the total agricultural research system with the direction required to satisfy future demands for its products. Even the broader planning efforts such as the concurrent USDA-SAES planning efforts, address usually only one and at best only two of the three dimensions of planning: (1) what it is feasible to do, (2) what it is relevant to do, and (3) how it is to be done (what is the allocation of resources). If the individual elements of the agricultural research system are to manage and operate their programs effectively, attention must be given to all aspects of planning.

There is need for an annually updated statement of research policy which in effect would constitute a national strategy for the U.S. agricultural research system. This statement--requiring input from biological, physical, and social scientists--should reflect the main thrusts of U.S. social and economic policies and indicate the impact of these on the agricultural research system as guidelines for designing research programs. These guidelines would reflect the realization of what can be accomplished with the resources available to the system, including reallocation of present resources, and provide guidance to those who are responsible for committing resources to it. Such guidelines should give attention to such areas as the extent, degree, and nature of the U.S. research commitment to the world food balance; the appropriate trade-offs between factors related to the more immediate problems of food safety and nutrition versus the longer term problem of maintaining a high rate of growth in food production; the relative commitment to high levels of food production with dependability of supply in the intermediate future (applied research) versus laying down a sound base for consistent growth in food production over the longer term (basic or fundamental research); the relative interaction among alternative long-term goals, such as a clean environment and eating; and other areas.

The need for a national strategy for agricultural research has become particularly critical at this time for two principal reasons: (1) the mission of agriculture has been broadened in scope and expanded in importance, and (2) the importance of agricultural research interacting with nonagricultural decision criteria such as land use, environmental protection, trade balances, and so on, is increasing.

Society perceives for the U.S. and U.S. agriculture a dominant position in resolving world food imbalances. This includes an expanded role in supplying foreign countries with the know-how to grow their own. At the same time, the American people, long accustomed to plentiful supplies of quality products, would like the food producing system to undertake activities to assure a return to the levels of expenditure for food as a part of total income that existed before the current inflation. Both of these charges to agricultural research require quick response. The principal implication of this is that the U.S. agricultural research management system must now produce more quickly even if costs are greater.

The present agricultural research management system is slow to incorporate such factors as energy, environment, and social, political, economic, and military constraints into its planning activities. When such factors are in fact reflected in plans, only marginal change in direction is achieved rather than the substantial redirections called for. A recognized national strategy for the agricultural research system might make possible important compromises among conflicting social goals. For example, a strategic withdrawal of key agrichemicals might be achieved based on a coordinated program of research to provide substitutes, thus minimizing loss of food production capabilities while achieving environmental goals.

A National Agricultural Research Policy Council (NARPC) is suggested as a means of communicating and deliberating among the diverse organizations and groups concerned with the many aspects of agricultural research. Reviews of programs, policies, and goals of agricultural research agencies and the agricultural portions of programs in other agencies having primary missions outside of agriculture would be an important assignment of the council. NARPC would devote itself to devising a general strategy for all agricultural research (social as well as biological and physical) to determine that a proper balance is reached between mission-oriented applied research and the long-range basic studies that must undergird future improved practices, institutions, and capabilities. It would also provide a forum for research sponsoring agencies in which information on plans and programs related to agriculture could be exchanged. It would be the agent for developing broad strategies to insure an efficient agricultural research system using the best capabilities of the nation.

Several desirable features of a NARPC can be stated. Its membership must be broadly constituted to provide a meaningful representation of the food sciences and the major interest groups related to food availability. It should have a limited staff, but it must be adequately supported by staff specialists from federal agencies and the SAES to develop the policy and strategy guidelines for the national agricultural research management system. The NARPC must be authoritatively constituted by at least the major components of the national agricultural research system to insure adequate attention to its guidelines. It must operate at a high enough level to have an overview of the total system including its technical, institutional, and human components and of the relevant linkages with the general economy and society. It must also have at least the power of review over agency and institutional strategies, but not over budgets or plans. It might also control some ancillary funding to facilitate initiation of the national strategies it designs.

The NARPC would not direct research but would lend direction to it. Its principal function would be to formulate consistent policy statements on agricultural research which, taken together, would constitute the national strategy discussed in the last section. With staff support, the NARPC would see that necessary information was collected and that studies were conducted on which to base guidelines. NARPC would also conduct reviews of agricultural research agency programs, missions, and goals, and it might have responsibility for promoting and providing guidelines for special grants programs in agriculturally related areas.

The NARPC should be established in a manner analogous to the currently constituted Agricultural Research Policy Advisory Committee (ARPAC) in the USDA and the SAES. The NARPC would also have representatives from other federal agencies sponsoring agriculture-related research. The list of representatives contained in the Sieberling Bill (H. R. 6737) represents the appropriate type of membership for NARPC. However, agricultural interests should predominate. Further, NARPC would not replace ARPAC, because the latter would still have an important function within the USDA family.

A RESEARCH MISSION FOR THE U.S. DEPARTMENT OF AGRICULTURE

The U.S. Department of Agriculture should include responsibility for research as a distinct mission.

The previous discussion was concerned broadly with the agricultural and agriculture-related research sponsored by some 15 or more federal agencies. Bringing these diverse programs into focus so that they can respond more readily and effectively to national and state needs is an important and challenging assignment. However, to most of these agencies food and agricultural production are secondary or peripheral responsibilities and of fluctuating interest. The major portion of the mission-oriented research directed toward the immediate and medium term needs of agriculture, that which will influence production over the next 10 to 20 years, is conducted by the affiliated SAES.

Many agricultural research administrators are of the opinion that USDA has not been an effective proponent of agricultural research, that it does not now provide for an adequate consideration of the problems and needs of research in its top-level deliberations, and that it lacks administrative and budgeting arrangements that can effectively guide research in response to national and regional needs.

The major agencies within the USDA responsible for research include the Agricultural Research Service (ARS), the Economic Research Service (ERS), the Forest Service (FS) and the Cooperative State Research Service (CSRS). The ARS conducts primarily in-house research in the biological, engineering, and physical sciences. The ERS conducts in-house research in economics and social sciences and provides policy analysis and other support for the Secretary. The FS has a research arm that conducts research on the management and improvement of the nation's forests and associated grazing lands. The CSRS administers federal funds that are primarily allocated by formulas to the 52 SAES and the Colleges of 1890. The federally appropriated funds provide an average of about one-third of the funds supporting the SAES and individual states supply most of the remainder. Closely aligned with the SAES are the state extension services that convey the results of research to farmers and consumers.

The total research conducted by these agencies in and associated with the USDA probably exceeds $700 million per year and involves over 10,000 scientists distributed in more than 100 separate locations. It is this complex group of research scientists that is devoting its efforts to the solution of the many problems of agricultural production, food processing, marketing, agricultural policy, and to the improvement of the quality of life for rural people.

Recently the USDA identified 11 major missions for program planning and resource allocation, but they did not include research as a mission. Research was included only as a supporting goal or function for such missions as "Agricultural Production Efficiency" which also includes many non-research activities such as the control and inspection work of the Animal and Plant Health Inspection Service. Other stated missions involving research in the social sciences include farm income, agricultural marketing and distribution, rural development, and food and nutrition. Support for nonfederal governments and institutions includes research funds allocated to the 52 SAES.

In the opinion of many concerned with representing research in administrative deliberations within and above the USDA level, the lack of a designated mission for research has been a significant impediment in bringing the role and contributions of research prominently before the principal councils of the USDA, the OMB in the Office of the President, and the Congress. Program and budget planning should consider research as a clearly identified responsibility to support the many missions of the USDA.

The USDA should restudy its roles and missions and identify research as a primary departmental responsibility. The supporting role of research and its relationship to each major mission should be clearly identified.

A PRINCIPAL ADMINISTRATOR FOR AGRICULTURAL RESEARCH

The Department of Agriculture should appoint a high-level administrator with staff to provide leadership of, coordinate, and be a spokesman for the research agencies and programs in the Department.

The USDA needs a top-level administrator with an adequate staff to keep abreast of research in the department and in the SAES. This administrator should devote his major time and interest to agricultural research, representing research in the highest levels of deliberations of administrators in the USDA, seeking financial and public support for agricultural research, and providing information exchange and coordination among the diverse research programs.

There have been suggestions that the staff support for such an administrator could be provided by CSRS, but a study of the present assignment and future program needs of CSRS provides convincing evidence that there is an important need and role for CSRS in helping to coordinate and strengthen research in the SAES. Also, the current staff and budget (3 percent of Hatch funds) is inadequate for the present assignment. If CSRS were to be the agency assigned the broad task of staff support for the principal administrator of research, the budget, staff, and organization of the agency would have to be greatly expanded. The question would also arise of conflict of interest for an agency working closely with one branch of research yet having a broad responsibility for all. In general, it seems most desirable that staff support for this office be independent of the several agencies reporting to the administrator.

The Secretary of Agriculture should designate and fill a high-level principal administrative position for coordinating all research in and affiliated with the department. The administrator should also be provided a staff of specialists to help the office keep abreast of the diverse research activities and the nation's agricultural research needs. These specialists should include biological, physical, and social scientists. This position should be at an assistant secretary level or the level of a primary assistant to an assistant secretary, and the staff should be independent of any of the research divisions being administered by his office.

ENHANCEMENT OF THE ROLE OF THE COOPERATIVE STATE RESEARCH SERVICE

The Cooperative State Research Service should be strengthened, and its mission and role assessed and reoriented to better promote and serve improved management of agricultural research.

Over a period of more than 80 years of administration of federal assistance to SAES, the CSRS has developed a restricted pattern of activities. While it was originally intended to coordinate the activities of the SAES with the activities of the federal agencies, the major current activities include the allocation of and accounting for federal funds appropriated for agricultural research in SAES and the Colleges of 1890, reviews of individual projects supported in part or in total by federal funds, the conduct of special departmental or comprehensive reviews within SAES, assistance in the administration of regional research, allocation and administration of competitive grant funds (primarily provided under P.L. 89-106), and representation of SAES programs within the USDA.

There is a growing need for more positive leadership roles in the operations of the federal-state research system which the staff of the CSRS could in part fulfill. This includes the need for more interaction with other federal agencies, sponsoring agricultural research, and critically reviewing fields of research and identifying new needs or opportunities for improved research activities. The CSRS could also assist SAES in improving their internal research review programs. Fulfillment of a more vigorous role by CSRS is limited by the perception it and the SAES have of its role, by the funds available for administration, and by the size, training, and capabilities of the staff.

The CSRS should critically evaluate its roles, missions, programs, and procedures. Representatives of other federal research agencies and SAES should be involved in evaluating present CSRS programs and possible future activities to encourage the evolution of a more effective and efficient agricultural research enterprise.

Additional highly qualified scientists should be provided to support a revitalized role for CSRS. Some staff support could be provided from funds now appropriated for forestry research and for the Colleges of 1890 providing the same 3 percent for administration that is currently included in the Hatch Act funds. Additional time for the existing staff could be made available by reducing the project review and approval process and placing greater dependence on the SAES for monitoring the quality of their own proposals within broad guidelines established by NARPC. Finally, a more dynamic and specialized role for CSRS staff might be fostered by using a larger proportion of short-term, temporary staff obtained while on leave from SAES or other agricultural research organizations.

STATE LEVEL COORDINATION OF FEDERAL-STATE RESEARCH

Orderly and periodic means for jointly reviewing research plans, budget requests, and programs at the state *level should be established by directors of SAES and area directors for the ARS and the ERS.*

In the SAES, stronger, larger, administrative units are needed to help design and operate the research programs executed by departments and individuals.

The limited administrative ties of research agencies at the upper administrative levels of the USDA are paralleled in many states by inadequate communication and planning at the state level among administrators of the SAES, the ARS, and the ERS. An orderly and periodic system of communication on such items as budget requests and future plans would relieve many current stresses and lead to better coordination of activities.

The director of each SAES should convene regular conferences with appropriate ARS and ERS administrators responsible for agency research in the state. In these sessions, research programs should be reviewed and evaluated and future plans, budget requests, and other matters of mutual interest should be discussed. The goal should be an integrated research program to meet the needs of agriculture and food consumers in the state.

FUNDING THE AGRICULTURAL RESEARCH SYSTEM

An adequate base of support for expanding agricultural research should be provided by means of an integrated program consisting of increased Hatch type funding to strengthen the federal-state research base, dedicated funding for the support of mission-oriented basic research not funded under existing agency or grants programs, and a system of competitive grant programs available to a variety of researchers.

Agricultural research within the USDA is budgeted through the Office of the Secretary and is assigned to the various agencies within the Department. Funds are provided through a number of different laws and regulations that often create rigidities that make efficient and effective program planning and implementation difficult. Appropriations for agriculture-related research to federal agencies outside of the USDA is independent of and often unknown to the agricultural mission-oriented agencies.

Associated with the diversity of the agricultural research system in the U.S. is an equal diversity in the sources of funds that finance the agricultural research. These consist of federal and state funds, private endowments, grants, and even self-generated funds. Within the federal funds, there are many individual sources sometimes financing the same or similar types of research. There is lack of coordination among this mixture of funds. Each has sprung up to fortify or protect a particular need and has then remained locked in place in the system. Many of the funding configurations are now obsolete and impractical. The functional needs of these funds are now different than when they were originally devised, yet the existing mixture continues to distort research programs in a manner that cannot be justified on the basis of priorities. One can see examples of this in the imbalance of funding among types of research, in funds that are locked into fixed geographical patterns of expenditure, in the "earmarking" by Congress to assure the welfare of specific interests, and so on.

Undoubtedly, some of the most productive support funds for any governmental program have been the Hatch funds. These funds permitted a buildup in research capabilities in SAES that contributed to the unprecedented food supplies in this country as well as other nations. Historically, much of the strength of the Hatch funds came from the formula base on which they have been allocated, essentially leaving to the SAES how these funds were to be used to best meet local research needs. Over a briefer history, similar developments have occurred in the federal agencies engaged in agricultural research through the allocation of general research support funds.

Several considerations arise with respect to such general funding. First of all, the existing research capabilities and facilities in the SAES and the ARS are there largely because of the Hatch and other general support funds. Another expansion of research capabilities in this country would require an expansion of Hatch or Hatch-type funds to augment existing research facilities and capabilities.

Growth in Hatch funds and other similar general support funds has not been as rapid as the increases in cost of doing research. One result has been a gradual deterioration of research facilities throughout the agricultural research system. There is now a broad need for an increase in funds of this kind simply to bring these facilities back up to their former productive levels. For many states, state funds have simply not been able to compensate for the decreases (in real terms) of federal funds.

The structure of research funding in the national agricultural research system is designed largely to support research at either end of the applied-basic research spectrum but not in the middle. On the one hand, funding of mission-oriented agencies centers on the solution of problems. In developing it, they conduct a program of basic as well as applied research; but the basic research is directed along lines of inquiry that are judged to be most productive to the eventual achievement of the desired technology.

From time to time, research reveals entirely new approaches which are alternatives to existing lines of inquiry in a mission-oriented problem. But however promising these insights may be, they must compete for funding with more applied research with more tangible potential and even with current lines of basic research for which it is considered an alternative. In an atmosphere of continuing pressures on budgets, funding generally comes only after the scientist has developed the concept on his own to a relatively advanced stage, however long it might have taken. On the other hand, the same type of mission-oriented basic research cannot effectively compete for funding with the type of research supported, for example, under an NSF program which tends to foster exploratory scientific endeavor and at the same time takes into consideration the availability of funding alternatives in its decisions.

The area of research depicted here may be potentially the most productive to support because it already has direct ties to the applied end of the research spectrum. Although it lies just beyond the horizon of what is visualized as eminently useful, its parentage is most often the practicing scientist gaining an occasional peek at what lies in that marginal zone of the yet unknown. While these areas will eventually surface, as the horizons are pushed farther back and the establishment conditions itself for their arrival, a great deal of precious time could be saved by taking advantage of these occasional opportunities and preventing them from slipping away. The national agricultural research management system must lock in the motivation and support to foster more effective research endeavors in this area.

A substantial program for competitive research grants for agriculturally related research could provide several advantages. First, it could provide a funding source for research talent from both inside and outside the SAES drawing into agricultural research many scientists who are currently excluded because of lack of finances. Second, it could provide a means of insuring that basic as well as applied research on agricultural questions is conducted, since it would enlarge the range of researchers into the more basic underlying sciences. Third, it could provide an incentive for maintaining excellence in agricultural research because grants are awarded in competition with other proposals under a peer-review panel system. Establishment of a grant system specifically for larger group efforts could stimulate needed interdisciplinary research efforts in agriculture. Such block grants have, in the past, provided bases for effective interactions of researchers in different fields of specialization who combine their skills to attack larger, more complex problems. One illustration is the Integrated Pest Management program currently supported by the NSF, EPA, USDA, and several SAES. Examples of much larger systems might include studies of drought strategies, tropical farming systems, and modeling of crop behavior.

Specific Recommendations for Funding

An effort should be made to bring together the diversity of funds that support the federal-state research system--in effect if not in fact. A comprehensive study should be conducted of the extent of multiple sources of funds, the effect of these multiple sources, and the practical possibilities for unifying them. As an intermediate step, the administrators and coordinators of the principal fund sources should reach some agreement with respect to the most effective pattern of funding for each source within the context of the overall fund sources and needs.

Serious study should also be given to a reassessment of the total structure, method of allocation, and general adequacy of the Hatch funds and similar general support funds for both the federal agencies and SAES. This should include a reexamination of the formula funding as a base for allocating resources and the examination of alternative bases for support. As we noted earlier, this report cannot attempt to reassess those parts of the agricultural research structure relevant to the sociological, political, and economic aspects of food production.

A mechanism should be set up immediately to provide a program of funding for deserving mission-oriented basic research that is not funded from existing sources. These funds should be open to all research agencies, organizations, and institutions and granted to the organization for specific research proposals as determined by peer and administrative review. However, the initial criteria should be that the proposed basic research is mission oriented. The program could be administered by the proposed NARPC or a Food Research Advisory Committee as recommended in H. R. 6737 (Sieberling Bill).

In conjunction with or separate from support for mission-oriented basic research, the USDA should establish a competitive grants program for food related research open to individuals, institutions, or consortiums on an equal merit basis. Likewise, funds should be open to research proposals over the full range of research from exploratory to developmental, but none to exceed three years. The principal criteria for selection should be the research contribution to increasing the availability and quality of food within the guidelines of an established national agricultural research strategy. The council or the advisory body administering the mission-oriented basic research funds could also administer these funds. Initially, funds might be generated by setting aside a percentage of total research funds. Eventually, such funds should be earmarked by Congress for this purpose as dedicated funds not subject to year-to-year exigencies.

Representatives of the federal-state agricultural research system should endeavor to reach some agreement with the NSF to permit greater representation by the agricultural sciences in the selection of projects to assure that exploratory research is conducted that will best serve the needs of food research in the long term.

RESEARCH REVIEW AND EVALUATION

Each agricultural research unit should assure adequate systems and criteria for the critical review and evaluation of research.

Some government research agencies, many SAES, and other agricultural research organizations have well designed systems for the planning, review, and critical evaluation of research. However, in too many instances these functions are carried out ineffectively. Strong encouragement should be given for strengthening these aspects of research operations.

Peer reviews of research have proven effective for exploratory basic or long-range research. Review of applied research oriented to the immediate solution of practical problems should include the opinions of those benefitted by the research--farmers, industry, and consumers--as well as the scientific peers of the researchers.

Various procedures have been used for research reviews. The CSRS has developed special or comprehensive types of review for programs within SAES. These reviews involve the selection of a panel of well-qualified peers, primarily from outside of the state and representing the major disciplines or specialities to be reviewed. Reviews have been devoted to evaluating programs and staff within a selected department, or they have covered the broad programs, disciplines, and scientists devoted to a commodity, such as corn or forage crops, or to a problem area such as reproductive failures of livestock. Such outside panel reviews have been well accepted and have been an effective means for improving research programs.

Critical review of individual research projects is commonly accepted as the primary basis for assuring a quality research effort and a wise investment of resources. Different review systems are used within SAES. Some SAES have a pool of well qualified scientists from which a panel of reviewers (frequently three) is selected for each research proposal. In other instances peer reviews are conducted primarily within concerned departments with further administrative reviews at the director's office level. These reviews emphasize, first, improvement of quality of research plans and, second, the rejection of poorly conceived and nonsignificant projects.

Research conducted to provide direct help to the public on a specific problem usually has an interested clientele. Representatives of these prospective user groups can be effectively used in evaluating the importance and possible applications of applied research.

Experience in administration of agricultural research indicates that critical research review is an essential aspect of effective research administration. Such experience indicates that a number of different types of reviews are needed to provide the flexibility necessary to adequate screening of the many diverse types and levels of research occurring in the broad spectrum of agriculture.

PROBLEMS OF AGRICULTURAL EXPERIMENT STATIONS IN STATE SYSTEMS OF HIGHER EDUCATION

A national study should be made of the changing place and role of agricultural research in land grant universities and in state systems of higher education.

The Hatch Act of 1887 provided for the establishment of an agricultural experiment station in each state in association with an agricultural college. For most states this marked the beginning of the land grant college system. Agricultural colleges were established or expanded to accommodate the agricultural experiment station that would receive limited federal support under the Hatch Act. During the following several decades, the SAES were usually the most prominent part of the agricultural college. General support continued to be provided by both the state and the federal government. Following World War I, the number of students grew, agricultural colleges became universities, and in each university numerous other colleges were organized among which agriculture became only one. In 1914 the Smith-Lever Bill provided for agriculture and rural people an extension service related to colleges of agriculture and associated with the SAES.

Following World War II, substantial funds became available for research in nearly all parts of each land grant university. The SAES that had hitherto been the major or even sole research arm of most land grant universities were now outstripped by research programs in engineering and in basic physical, biological, and social sciences. The number of students seemed to explode. States created numerous additional universities and colleges, and research institutes and centers were set up to manage and promote burgeoning research in nearly all parts of the major universities.

Soon the complexity and costs of higher education demanded statewide administrative organizations which dealt, to varying degrees, with such questions as definition of the mission and program of the individual institutions, and general budgetary allocations.

The role of the SAES and the colleges of agriculture seemed to shrink. The agricultural experiment station became only one of a number of major research programs in the university system, and the understanding and appreciation of agriculture often seemed relegated to secondary importance in the system.

As of the 1970s the changes and organizational policies of higher education seem to have reached a crucial point. State systems of higher education are by purpose and policy primarily concerned with students and with rationalizing educational programs. Academic research, supported largely by grant funds but still demanding a substantial portion of faculty time, has lost its luster. Mission-oriented research often has even greater difficulty fitting into these systems, particularly when it seems to compete with educational programs for space and financial support.

Following the post World War II expansion, agriculture--which had become a combination of the college, the agricultural experiment station, and the extension service--frequently retreated from its dominant role in the university to what the Mayers characterized as "Island Empires." But today this retreat and isolation is no longer defensible: programs of agricultural research can only be maintained if they receive an equitable share of state and federal funds and if agricultural scientists receive equitable treatment and recognition in institutional merit systems.

To further augment agriculture's problems, an increasing number of state legislatures are now under urban rather than rural domination, and a different set of interests and backgrounds must be appealed to. In addition the agricultural experiment station director in an increasing proportion of cases must work his requests for budgets and program authorization through an administrative maze consisting of the college dean, the university administration, and boards and chancellors of statewide systems of higher education before those requests can even go to the state legislature. Within these systems, dominating concerns for the student and for education often result in criteria for new faculty, space in buildings, and program support based almost entirely on numbers of students.

Increased attention by the SAES research system to pressing social problems would justify increased investments in research on the socio-politico-economic aspects of food production. Such research is now being done by federal, state, and private agencies and social scientists who are often not fully conversant with agriculture and food problems. Some of the funds now used in this way and additional funds could be advantageously used and managed in the university land grant system whose administrators and scientists are well acquainted with problems involving food.

Agricultural research in changing state systems of higher education calls for careful analysis and new alternatives in administrative arrangements. Also, consideration must be given to whether or not the point has been reached where mission-oriented research and educational systems are incompatible. If they are, what are the alternatives? This is a question that has received little national attention and has seldom been openly explored.

Some states have established ways in which agricultural research administrators can make direct contact with members of the state legislature. Others work around the educational system through representatives of agricultural industry or commodity organizations. Various alternatives for strengthening the voice of agricultural research and for improving the effectiveness of research management are needed, and an independent study should be conducted to evaluate those alternatives fairly in relation to the best interests of society.

ENCOURAGING EXCELLENCE IN RESEARCH

Agricultural research organizations should establish reward systems that adequately recognize and encourage excellence in all aspects of agricultural research.

In agricultural research there are many types of endeavor not adequately measured by traditional, restrictive research reward systems. Often the product is a new crop variety or a new production or processing practice more suitable for immediate use by farmers or other clients than for publication in referenced scientific journals. Even though such types of productivity often do not receive high marks in typical peer review systems, they are the foundation that primarily justifies public support of all research. Attraction and retention of the most able scientists in applied research require that the system of merit recognition be as good for applied accomplishments as for the more often acclaimed basic research.

If the previously described flexible systems of research review and evaluation are implemented, the remaining limitations on an equitable reward system involving advancement in rank and salary are in the internal criteria and advancement system of each organization. In many organizations, discrimination against applied research does not exist. Strenuous efforts must be made in all cases to have an equitable, unbiased evaluation and merit reward system.

CHAPTER 4

TECHNOLOGY INNOVATION IMPROVEMENT FOR THE WORLD FOOD SYSTEM

INTRODUCTION

The U.S. and other developed countries cannot produce and export more than a small fraction of the food required now and in the future by the burgeoning populations of agriculturally developing nations. Furthermore, the economic and social welfare of these countries seem best served where the country is self sufficient in food resources.

The primary focus of this report is on recommendations for agricultural, food, and nutrition research that, if implemented, would enhance the production and stability of food supply in the U.S. Nevertheless, it was felt advisable to make some observations regarding the solution of food problems abroad. It is hoped that a more comprehensive study of the worldwide situation will be undertaken.

Production of adequate food in most developing countries requires the wise use of available land and water resources and the development and adoption of improved technologies. This section of the report does not explore all the many factors involved in maximizing food production, such as economic incentives and public policies; rather we are concerned here with developing and implementing the scientific and technological capacity to enhance food production in each country.

Most developing countries have established agricultural research programs, often inadequately supported and staffed and without adequate modern facilities. Such nations could be helped in developing their capacity for technology innovation and management by collaboration with experienced agricultural scientists from other countries. The U.S., along with other developed countries and international institutions, can provide much of this needed assistance, but its provision must be planned and implemented in cooperation with national leaders and their agricultural scientists. The U.S. should function as a part of the international technical assistance community consisting of scientific technical assistance groups from various developed countries, foundations, and international research centers. For example, international agricultural research centers, sponsored by 29 nations and foundations, and coordinated by the CGIAR, have assumed a central international role in agricultural research devoted to increasing world food supplies. These centers are developing new varieties of major crops suited to diverse world conditions and are solving problems of disease, parasites, nutrition, and production practices to improve livestock productivity. Additional programs concentrate on labor intensive innovative farming systems and related technologies adapted to small farms and applicable to various conditions of soil, water supply, and climate. Most of the centers are developing satellite research programs and outreach activities that are making new seeds and other technologies available on every continent and in many developing countries. The goals are labor intensive technologies with resultant increased crop productivity.

The capacity to invent, adapt, and diffuse technology has expanded at both the national and international level in the last decade. As the flow of new technology has accelerated, sociocultural factors have loomed as serious constraints on the growth of agricultural productivity. This places a high priority on the development of research capacity in the several social sciences in developing countries and lends urgency to social science research on problems of cultural and political structure.

Most of the research leading to more effective institutional performance, including policies that contribute to productivity growth, must be done in the country in which it is to be used. There is, however, need for regional collaboration among related social science researchers and for a capacity to focus institutional attention on problems of pressing international significance. Ways should be sought for strengthening the U.S. agricultural research system capacity that will make a more effective contribution to institutional performance.

Technical assistance programs require continuing assessment and adjustments if they are to benefit from experience and from changing situations and institutional characteristics. The needs of the agriculturally developing countries include the following:

1. improved capacity to formulate national research needs, arrange them according to priority, and organize programs for their attainment;
2. strong institutions to conduct effective research and development programs: of particular importance is site-specific adaptive research;
3. trained manpower to carry out diverse technology innovation management programs; and
4. effective communications networks.

U.S. institutions managing effective technical assistance programs should possess the following qualifications:

1. a clearly identified role in international technical assistance programs (institutions often develop

special capabilities, such as production of tropical crops or management of water on the farm);

2. a strong and consistent performance record in international technical assistance programs as evidenced by the use of well-qualified staff members and capable backup support; and

3. adequate resources for management and support of international programs: only federal support on a continuing basis can enable most educational institutions to develop and maintain strong international programs.

The diverse international community of donor and recipient countries is an ever-changing mixture of needs, problems, and social and political attitudes. The major consideration for an effective U.S. role in technology innovation management systems for improving world food production and supply is a program flexibility that can adapt to these changing needs of the recipient countries, each of which must build its own capacity for technology innovation management.

STRATEGY DEVELOPMENT FOR TECHNOLOGY INNOVATION MANAGEMENT

A national strategy should be encouraged for U.S. involvement in technical collaboration in agriculturally developing nations.

The U.S. does not currently have a consistent strategy for increasing world food production or providing technical assistance in technology innovation. The nation does support a wide range of activities devoted to this end from which can be derived some appropriate elements, but these activities are not coordinated under a single strategy or long-term plan of action. A national strategy would provide a set of expectations useful to the numerous institutions of the U.S. and those of agriculturally developing nations involved in devising long-term programs.

National interests of the U.S. can be grouped under such headings as economic, scientific, humanitarian, and, possibly, others like the national security. Under economic interests two issues are significant. Some data show that as growth occurs in agriculturally developing nations, imports increase from the U.S., even imports of agricultural commodities. Whether that situation prevails over a broad range of conditions can be determined. The second issue concerns another aspect of world commerce. With the 1971 devaluation of the dollar, U.S. food became relatively cheaper for other countries, and the U.S. consumer was placed in closer competition with the world's hungry than he had been before.

Two science issues of national interest can be identified. One involves the contribution the rest of the world can make to our own agricultural, scientific, and technological expertise and the progress we can make through experience in the rest of the world. The other involves the nature and quality of training of our students and their impact on international collaboration.

The humanitarian issue involves American values, philosophy, and traditions. Historically, this nation has been uncomfortable with realities of starvation, poverty, and disease existing anywhere in the world. At the same time it places high value on education and self-reliance. The development of U.S. strategy will require consideration and judgment with respect to these apparently conflicting national attitudes. National security and perhaps other elements in the national interest must be analyzed, but their consideration requires specialists outside the coverage of this report.

Strategy development also involves identification of the limiting factors and analysis of the time and resources needed to reduce or eliminate them. These must be identified and analyzed at useful or manageable levels of generalization. For example, if the supply of trained manpower in the U.S. will set limitations, this impediment must be overcome before other limiting factors can be addressed.

Finally, the resources available must be evaluated. Money is only a small part. Of greater, obvious significance is the finite pool of scientific manpower and the science-technology organization. Of less obvious significance is the complex of organizational and managerial skills in the U.S., but this resource may be of considerable usefulness if deployed appropriately.

The area of resource identification, evaluation, and allocation probably involves the most significant issues. The U.S. has accumulated more than 100 years of experience in agricultural development and technology innovation, both domestically and internationally. Strategically, it would be helpful to evaluate the usefulness of that experience to agriculturally developing nations along with the magnitude of the task involved in harvesting and processing it.

Another resource is manpower. The U.S. has a large pool of trained manpower and extensive manpower training facilities, but both the pool and the facilities have glaring deficiencies which must be corrected. A profile of manpower expectations must be drawn as a basis for rational investment in human resource development. The availability of manpower and its capabilities for aiding agriculturally developing nations needs particularly critical evaluation.

A related issue is the means of mobilizing, organizing, and deploying human resources, which reside in several federal agencies, more than 50 state universities, and many private firms. It is a resource that represents experience in development and management-programming as well as in scientific and technological matters.

The financial resources the U.S. can afford or is willing to invest in this endeavor is also a limiting factor.

Strategically, analysis of the following factors should be useful:

1. inadequate supply of U.S. manpower trained to the worldwide task;
2. inadequate supply of trained manpower in agriculturally developing nations;
3. inadequate organization of the technology innovation machinery in agriculturally developing nations;
4. inadequate organization and management of the world stock of knowledge of agricultural science and technology;
5. inadequate mobilization, organization, and financing of U.S. human resources; and
6. inadequate mobilization, organization, and financing of U.S. educational resources.

The development of a national strategy will involve many entities whose broad participation will be necessary in arriving at a national consensus. Private as well as public groups should be involved. Government leadership in initiation and organization should probably come from the executive branch, although Congressional committee leadership is an alternative. Certainly, the Congress should participate. Within the executive branch, responsibility has already been placed with USAID to chair a coordinating committee of federal agencies involved in development assistance, and perhaps this agency could organize the larger effort. Another alternative could be a special presidential commission, such as the President's Science Advisory Committee of 1967.

The USAID should take the initiative to improve the capacity of agriculturally developing nations in technology innovation.

Guidelines are needed to make technological innovation more efficient and effective. These guidelines must address the essential functions that have to be performed and help management accommodate to the specific situation of a country. Given the current state of the art, such guidelines cannot be specified in recipe form. However, the following are some aspects of management that must be taken into account.

1. Agricultural technologies adapted to the specific natural conditions under which farmers operate: the most important are soil characteristics, climate, and the nature of the terrain. These technologies require strong national research institutions with sufficient regional scope to encompass all the significant producing areas in the country.
2. Incentives and disincentives for farm producers and other entrepreneurs: government price and exchange rate policies sometimes distort price relationships in a way

that discourages farmers from adopting new technologies, or induces them to adopt technologies inappropriate to the endowment of the country (e.g., capital intensive as opposed to labor intensive technologies). Credit policies are often such that small farmers are unable to purchase technological innovations, or innovations may be unavailable because of import restrictions, insufficient domestic production capacity, or inadequate transport and storage facilities.

3. The spread of technological knowledge: farmers must be informed of new technologies and instructed in their use. This will involve such nontechnological activities as nonformal education, extension programs, demonstration farms, and regional agricultural fairs. Suppliers of agricultural credit and input and product marketing services to farmers must also learn new ways.

(4) Participation of agriculturally knowledgeable people in the public decision-making process: food production is the leading industry in most agriculturally developing nations. Most public policies have important implications for agriculture. Yet, national interest in development of a strong, scientifically and technologically based agriculture is frequently underrepresented in policy decisions. There will be no change without a strong national commitment to modernized agriculture.

Understanding the process of technological innovation in agriculture is the first step in improving its management. Once the basic elements are identified--from development of location-specific technologies to their diffusion throughout the farm sector--each element can be addressed individually from a research standpoint, and the management problem of identifying and removing limiting factors can be clarified.

Through the efforts of national and international research institutions in both agriculturally developed and less developed countries, an effective beginning has been made on the problem of technology innovation. In addition, there have been significant experiences in the management of technological innovation from which the knowledge produced has not yet been harvested, such as the Puebla experience in Mexico (a program to improve corn production on small rain-fed farms), the Masagana 99 experience in the Philippines (a national rice production program), and various national experiences with high-yielding varieties of rice and wheat. Much additional research in the agriculturally developing nations is needed, however, to expand knowledge of technological innovation and improve the capacity to manage it.

Immediate steps should be taken to establish an organization for funding and coordinating activities of state, federal, and private institutions in the planning and management of technology innovation programs. Long-term support for U.S. institutions involved in international technology innovation management programs should be provided.

Programs of technical assistance or cooperation are characterized by a variety of performers, resources, and agencies and institutions governing their policies and directives. Well over a dozen federal agencies, more than 53 universities and colleges, and a number of private institutions are involved in the conduct of agricultural technology transfer activities. The skilled resources used by these performers are widely scattered and often organizationally bound. The contractors of these activities, who set policies and establish programs, include five separate bureaus in USAID, various other federal agencies through various bilateral agreements, the World Bank, private foundations, CGIAR, and others.

In the past, coordination among these many agents has occurred through a variety of communicative devices. It has probably worked reasonably well when the status of agricultural development efforts and the environments to which they were applied are considered. Nevertheless, each of these technology innovation management institutions generally operated independently of the others. This has led to a number of shortcomings in the use of resources, such as a tendency to partial rather than total system evaluation, a lack of relevant capabilities in certain areas of a program, selection of programs based on resource availability rather than relative importance, and assistance that was not balanced with the needs of the recipient country. What might have been an acceptable form of organization under past conditions is of questionable adequacy now. In total, the current organization is not geared to handle the technology innovation management requirements with which it must cope now and in the future.

Whatever mechanism is devised for improving coordination among the various components of the technology innovation management system, it must at least meet the criteria of being a permissive mechanism rather than a restrictive, administrative one. The diversity of environments in which technology innovation management occurs requires this, and the available resources must fit in with rather than be fit to these environments. This would suggest a mechanism that provides policy guidance rather than specific programs. Such guidance should reflect the inputs of the principal participating institutions.

The mechanisms for facilitating coordination among the various institutions should provide the opportunity for an enduring partnership between state, federal, and private institutions in the planning and management of technology innovation programs.

Consider the example provided by the U.S. in the relationship between federal agencies and land grant universities in matters of technical assistance. The federal agencies have access to the budgeting process. They provide logistical support of diplomatic and technical missions, they give the mandate to administer the U.S. foreign assistance programs, and they play a role in the financing and program direction of the international centers. They need research, training, and advisory services from colleges and universities to develop the manpower required for both domestic and overseas activities, involving citizens in both the U.S. and in agriculturally developing countries. The universities provide experience in basic and applied research, the training of native and foreign students, and the transfer of technology through the cooperative extension service. Many of the land grant universities have a commitment to, and experience in international activities while maintaining a strong domestic backstopping capability. U.S. universities, however, lack the adequate and reliable long-term funding to maintain continuity in their international program efforts.

Short-term support of international programs conducted by universities either takes capable faculty away from its regular assignments or forces the university to seek other available manpower. In the first instance, university programs suffer; in the second, the international program may be reduced. With assured long-term funding a university can add quality scientists to its permanent faculty, provide additional trained human resources, and make the international program a part of its overall program.

A similar situation exists with USDA involvement in international activities. The considerable capabilities of the numerous institutions in the private sector that have expertise in the development process should also be included in addressing this problem. Support to governmental agencies could be provided through appropriate federal legislation. Incentives for institutions in the private sector could be provided through contractual arrangements.

Title XII of the Foreign Assistance Act (H.R. 9005, July 29, 1975) provides a program for strengthening the capabilities of universities and other U.S. institutions and international agricultural centers to solve food and nutrition problems of developing countries. Favorable action on this or similar legislation would provide an organization and funding mechanism for a strengthened U.S. international technical assistance program that could be developed to encompass the capabilities of various federal agencies and the private sector as well as the educational institutions.

<u>Continuing support should be provided for international agricultural research centers as now coordinated by the Consultative Group for International Agricultural Research.</u>

The cooperation of a number of nations and international foundations in the planning, development, and support of international research centers is a recent innovation. Centers dedicated to the development and adaption of technologies to improve food production in agriculturally developing nations represent one of the most significant international programs evolved in recent years. Ten have been established with an aggregate budget of approximately $50 million for fiscal 1976. Others are in the planning and development stages. These centers have come to fill an important role in agricultural development through the perfection of new technologies and their release to agriculturally developing nations to insure high levels of production and the conservation and effective use of natural resources.

Several unique features have been helpful in making the programs of these centers effective, among them an international diversity of scientists, continuing support assured for relatively long periods, relative freedom from political and social pressures in the individual participating countries, and strong commitments to the solution of specific problems. The U.S. currently furnishes about one-fourth of the financial support for each of these international centers. Continued support at approximately this level is strongly recommended.

It is recommended that the U.S., in cooperation with other countries, promote and assist the development of international research and development networks for assisting improvement in agriculturally developing nations. National adaptive research and associated extension programs need guidance and strengthening to enable individual countries to make effective use of information coming from international agricultural research/technology transfer networks. The components of this network include developed countries' research institutions, international centers and related regional institutions or programs, and the national research systems of the developing countries.

U.S. programs of direct agricultural assistance will need careful planning and adjustment if they are to relate most effectively to international programs. A unified set of programs that mutually reinforce each other should be the primary goal.

The United States should establish one or more centers to conduct research and train scientists in problem areas important to agriculturally developing nations but not of major importance in this country.

An immediate need is a center to study agricultural production in the humid tropics and another for the semi-arid tropics. The centers could give attention to soil, climate, water management, and crop production practices and cropping systems.

The tropics furnish one of the greatest potentials for enhancing world food supplies. The U.S. is providing technical help for many countries in the tropics, but in general U.S. scientists are not experienced or well-informed about the problems of this vast region. In consequence, our assistance has not been as wise or effective as necessary. Individuals, through long experience, have become well informed. However, there is no adequate mechanism for transferring the benefits of their experience to others; and, of equal importance, there are neither facilities nor adequate support for intensive research in the U.S. on technical problems of tropical agriculture.

The International Agricultural Development Service (IADS) has recently been formed, supported by The Rockefeller Foundation and incorporated in the State of New York. Its purpose is to assist interested developing countries, individually and collectively, to accelerate agricultural production and rural prosperity while strengthening their institutions to permit sustained progress with minimal external assistance. The service is expected to complement and support the work of developing country institutions, the international agricultural research institute, universities, international and bilateral technical assistance and lending agencies, and private organizations.

IADS is an autonomous, nonprofit, self-supporting, apolitical, technical assistance institution. It is governed by a self-perpetuating board of trustees comprising emminent authorities on agriculture and rural development. A technical advisory board composed of specialists from the developing countries will be formed, and an international, interdisciplinary career staff of highest caliber will be recruited.

IMPROVING THE STATISTICAL GATHERING SYSTEMS OF DEVELOPING COUNTRIES

Programs should be initiated to transfer and adapt to agriculturally developing countries the new technologies being generated in the U.S. and in other countries for obtaining and analyzing agricultural and food data.

The traditional principal suppliers of statistics of agricultural production, food distribution, and nutritional status in the international arena are mainly FAO, USDA, and the International Wheat Council. Screening the flow of information from these and other sources is an overwhelming problem. In the same way, questionable reliability, timeliness, usefulness, and accuracy of information provided by governments seriously impede the decision-making process, in both analysis and planning.

The USDA should make available assistance for manpower training, methodologies, and for field assistance to help countries develop improved systems for gathering reliable data on agricultural production, food distribution, and nutritional status of the people. This assistance should be in cooperation with the agricultural statistical gathering programs of FAO.

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CHAPTER 5

CONSTRAINTS ON U.S. AGRICULTURAL PRODUCTION AND RESEARCH: FEDERAL REGULATIONS AND LEGISLATION

INTRODUCTION

Study of the technological opportunities for the expansion of agricultural production shows clearly that a large contribution may be expected from scientific research. This positive conclusion must be tempered, however, by the realization that a broad range of restrictions may influence not only the adoption and use of new scientific developments, but the very research process that generates them. The body of this report deals with the potential of new scientific findings through research, but a cautionary note should be added on constraints that may limit their generation and use.

Emphasis is often given to constraints that limit agricultural production in the agriculturally developing countries. These constraints include a host of economic, social, cultural, and political factors. Most of them are well recognized and discussed in the literature: for instance, arbitrary pricing policies for inputs and outputs; inadequate credit and marketing institutions; lack of modern inputs; poorly functioning teaching, research, and extension institutions; and inequitable and impractical land tenure arrangements.

Less well understood, however, and somewhat paradoxical, is the increasing chain of constraints that bear directly on the generation and adoption of technology in the U.S. Attention has been given, of course, to the effects of price and production controls. Under pressure of increased demand for food products, however, a freeing up of the market appears to be taking place. Nevertheless, there is considerable room for relaxation of restrictions that derive from imperfections in competition stimulated by private and public actions.

A comprehensive analysis should be made of the cumulative effect and total cost of federal regulations and legislation on U.S. agricultural research and production.

Increased attention should be focused on the growing body of government (state and federal) legislation and regulations that have been adopted to enhance environmental quality and assure human safety which, in the process, may constrain agricultural activities. A summary is not easily made, nor will an attempt be made to analyze the broad range of measures that are being taken to control air and water pollution, waste disposal, chemical residues, and genetic variation; to protect endangered species; to zone land for agricultural use; to restrict the development and use of water resources for agriculture; and to regulate the use of agricultural labor. Instead, the description of some U.S. legislation and regulations will indicate the impact that is felt by the agricultural producer and researcher.

PUBLIC LAW 91-596
OCCUPATIONAL SAFETY AND HEALTH ACT OF 1970

This Act, administered by the U.S. Department of Labor, includes concerns for the safety of all agricultural workers. Attention is being given to safeguards against such potential hazards as nuisance dusts, noise, chemicals, animal handling, equipment, tools, and facilities. Considerable research in agricultural and human engineering will be necessary to meet the requirements of this Act.

PUBLIC LAW 92-500
FEDERAL WATER POLLUTION CONTROL ACT AMENDMENTS OF 1972

This Act, administered by EPA, is still in the process of implementation. It includes provisions for the control of nonpoint source pollution of navigable waters resulting from runoff from land used for agricultural livestock and crop production. In view of the Act's broad definition of "navigable waters," much of the prime agricultural land of the U.S. is essentially contiguous to "navigable waters," and therefore subject to some regulation.

Good agricultural practice has long endorsed conservation of the land and the establishment of systems to constrain the movement of soil and its attending chemicals. Soil conservation practices have been employed where economically and physically feasible. But to fully constrain all movement of soil and chemicals essential to crop production from much of the nation's agricultural land by 1985, as called for under the Act, may entail major changes in cultural practices, land use patterns, types of crops grown, and in the conventional handling of dairy and beef cattle as well. The achievement of these ends could require a substantial redirection of research efforts by plant scientists, soil scientists, hydrologists, engineers, and others in both the public and private sectors. And the economic impact on farmers as they affect production must also be considered.

In addition, the Act defines as point sources of pollution return flows from irrigation systems used in crop production in the arid areas of the West. As such, irrigation return flows will be required to meet established limits for identified pollutants they have picked up while draining from agricultural lands. New technology will have to be developed before farmers will be able to comply with this portion of the law.

PUBLIC LAW 92-516
FEDERAL ENVIRONMENTAL PESTICIDE CONTROL ACT OF 1972

This Act, administered by EPA, regulates through a process of registration the availability and use of all agricultural pesticides on the basis of benefits and risks to environmental and human safety. The agricultural chemical industry provides the scientific data on which the agency bases its decision whether or not to register a product for use.

Research data requirements for registration, as they increase in number and scope and become more finite and structured, will act as economic disincentives to the pesticide industry. U.S. companies will either be discouraged from further risk taking in long-term R&D, or they will move critical portions of their R&D effort, as well as considerable production, into foreign countries where they can serve an expanding world market. The latter development in particular should be avoided to prevent any dependence of U.S. agriculture on the importation of the pesticides and pest control technology essential to contemporary pest management.

PUBLIC LAW 93-205
ENDANGERED SPECIES ACT OF 1973

This Act, administered by USDI, protects any species which is determined to be in danger of extinction (other than economically destructive insects) and includes without limitation any mammal, fish, bird, amphibian, reptile, mollusk, crustacean, arthropod, or other invertebrate and any member of the plant kingdom. USDI has named 108 endangered animals and has under review a proposal for listing as endangered species 42 genera of butterflies, 67 fresh water crustaceans, 61 mollusks, and 7 fresh water sponges. The Smithsonian Institution recently completed and submitted for consideration a list of some 2,000 plant species it considers endangered. The above species are widely dispersed throughout the U.S. Once a species is named on the endangered list, its "critical habitat" will be determined according to vital needs, including space for normal growth, movement or territorial behavior, and conditions to satisfy other biological, physical, or behavioral requirements. Actions USDI may implement to protect the "critical habitat" include the development of regulations, acquisition of land and water leasing arrangements, and other administrative and management plans and activities.

Considering the diversity of endangered species already named and under consideration and their distribution across the nation, it is indeed likely that "critical habitats" will be identified on and in the vicinity of agricultural lands now in use and on potential agricultural lands, such as open ranges. Therefore, under the administration of this Act the protection of a "critical habitat" for each endangered species could have the force of withdrawing land from commercial use, quite possibly without purchase or upkeep responsibility, and future expansion of agriculture to new lands might be effectively blocked by prior identification of an "endangered species" in the area of projected expansion.

FDA, GRAS REGULATIONS
TITLE 21 - FOOD AND DRUG, CHAPTER 1, SUBCHAPTER B, PART 121 - FOOD ADDITIVES, SECTION 121.3 (b) (2) (ii)

These regulations, administered by the Food and Drug Administration (FDA), require that the FDA be notified of the introduction of new varieties and strains of food crops for which the nutritional or toxicological constituents, or both, are significantly altered by breeding or selection.

The major nutritional constituents of most food crops, especially those considered important in the daily diet, are evaluated in new varieties, and such evaluation should be continued. However, it has not been routine practice to analyze for naturally occurring toxicants. Although the occurrence of toxicants in many common food crops has been known for many years, little is known about the hazard they pose to human health at levels normally found in commercial varieties. The NAS has since identified a broad spectrum of toxicants occurring naturally in food, but the possibilities of introducing new toxicants through genetic manipulation aimed at developing new varieties to repel, inhibit, or kill pests have not been considered. If such toxic constituents occur in the edible portion of the food crop, the FDA regulations must be observed and toxicological studies undertaken to determine the hazard to human health.

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PART TWO

SECTION I: HUMAN NUTRITION

INTRODUCTION

Providing adequate nutrition for people is the basic purpose of food production. People need nutrients for their physiological well-being, and to meet this need they consume food. The difficulty frequently experienced in understanding and resolving nutritional problems involves this relationship. Agricultural production provides, for most of the world's cultures, the foods which are the carriers of the essential nutrients. The amount and variety of food that is available, its cost, acceptability, and nutrient composition determine the ability of individuals and a population as a whole to fill their nutritional needs. As we contemplate changes in food production to provide better nutrients for people, it is important to consider the influence of food preferences and eating habits on the actual intake of nutrients.

The nutritional status of individuals and populations may be revealed in a variety of ways. Acute disease may result in humans directly from nutritional deficiencies, particularly during periods of food shortage. Chronic deficiencies, frequently characterized by poor growth and development, may also exist where the specific nutritional deficiency is not well defined. Excesses of particular nutrients may also cause chronic or less commonly acute diseases. Knowledge of nutrient requirements and their interrelationships under the varied environments of human existence is of fundamental importance. There is also a need for improving our ability to transfer information concerning nutritional needs to the foods people consume, and conversely to evaluate nutritional status from information about the food consumed by individuals and populations. There is a need for evaluating in a cost-effective manner the nutritional status of human populations. With this information--knowledge of food consumption and food composition--it will be possible to assess more adequately the nutritional status of individuals and populations and to develop programs to maintain or improve their status.

Greatly increased support for research on nutrition and food science is needed to determine the nutrient requirements, nutritional status, and food consumption patterns of people as well as the nutrient composition of raw foods, the effects of food processing, storage, and preparation and the cost--in energy and materials--of alternative ways to improve the nutritional status of populations. The following chapter discusses specific recommendations concerning such research.

CHAPTER 6

NUTRITION RESEARCH

RECOMMENDATIONS

1: Nutrition Surveillance. Efficient and inexpensive methods are required for determining the nutritional status of individuals and populations.

2: Food Consumption. Since people require nutrients but eat foods, it is essential that proper methodologies be developed to determine what individuals and populations eat and what factors influence their choices.

3: Food Composition. To translate food consumption to nutrient intake it is essential to have accurate and timely information on the nutrient composition of foods, compiled in a manner that permits continued updating and rapid retrieval. Continued development of this capability is an essential part of a national nutrition program.

4: Nutrient Requirements of Man. Research is critically needed to more accurately define the nutrient requirements of man and those factors in his environment that interact with or influence the need for essential nutrients.

5: Food Intervention. Methods should be developed to evaluate the potential impact of intervention programs on the nutritional status of the target group so that the cost-effectiveness of the program can be evaluated on a timely basis.

6: Constraints. Various factors that potentially contribute to the problem of improper nutrition in the U.S. should be analyzed to determine the major constraints involved.

NUTRITION SURVEILLANCE

Rationale

A prerequisite for the introduction of intervention programs to improve the nutritional well-being of a population is sound knowledge of the magnitude and extent of nutritional deficiencies by geographical areas, income levels, age groups, and other identifiable segments. A properly designed nutrition survey can provide this base line information and guide programs designed to alleviate the particular nutritional problem identified, such as protein calorie malnutrition, iron deficiency, or vitamin A deficiency. Repetition of the nutritional surveillance at predetermined intervals is essential to assess the impact of an intervention program that has been instituted. It is particularly important that surveillance be maintained on vulnerable groups in society, such as children or lactating mothers.

Properly fashioned, these surveys can provide an early warning system to alert governments to potential nutritional problem areas and prevent problems from evolving into disasters.

To be most useful, methodologies for determining nutritional status must be reliable, efficient, inexpensive, readily implemented, and capable of being carried out by nonprofessional but well-trained personnel. Methods for assessing nutritional status in use today range from simple anthropometric measurements to elaborate use of clinical measurements as in the Interdepartmental Committee on Nutrition for National Defense (ICNND) surveys. We need a careful evaluation of existing techniques and development of a uniform methodology that can provide accurate and comparable nutrition information on a worldwide basis. Whatever methodologies are used, it is essential that the measurements reveal accurately the nutritional status of the individual and/or population group surveyed.

FOOD CONSUMPTION

Rationale

Since people require nutrients but eat foods to obtain these nutrients, it is essential that we have sound information on what people eat. A course of action to meet food production and nutrition needs must be based on the composition of the foods that are consumed. It is urgent that we get this information now to guide other facets of an overall food and nutrition program.

Food consumption practices differ among individuals and among different income and population groups. To plan for the nutrient food needs of those individuals or groups potentially at nutritional risk, information must be developed on the types and amounts of food consumed. Continued surveillance of food consumption habits will describe the current food intake and, over time, will alert agencies to changes in food consumption that may be altering nutritional status.

The food consumption practices of the infant, the pregnant and lactating woman, and the rapidly growing adolescent must be known if malnutrition or other health problems related to nutrition are to be avoided, or if effective food intervention programs are to be mounted. For other population groups beyond the so-called "target groups," however, food consumption surveillance may also be needed since diet has clear implications for serious health problems, such as heart disease, goiter, and anemia.

Research is needed on the development of less expensive methodology for deriving information on the safety of foods. Food contaminants or microbiological metabolites may pose hazards to particular population groups consuming large amounts of a suspect food. Some food additives when consumed excessively may create risk of toxicity or interfere with the consumer's benefit from certain key nutrients.

Numerous food intervention programs are now being funded by Congress but little or no data is being accumulated on how these programs are influencing food consumption or nutritional status.

FOOD COMPOSITION

Rationale

To interpret the nutritional significance of food consumption patterns, diets need to be analyzed for the variety and quantity of nutrients they contain. The biological or metabolic usefulness of the form of the particular nutrient as it exists in a food must be known, since some nutrients in certain foods may be relatively unavailable for use by man. The many steps that a food must go through from production to consumer may have marked effects on the ultimate nutrient composition of the diet. Current programs in nutritional labeling of foods require that this knowledge be generated. Up-to-date reference tables on the nutrient composition of foods as consumed are needed for the various regions and nations of the world. As new food products are developed and accepted into the diet, data about their nutrient composition must be compiled. Losses and wastage that may be encountered in transportation, storage, processing, and preparation also need to be known.

Breeding programs oriented toward nutritionally improved varieties of food crops must be based on knowledge of the nutrient composition of foods and of natural toxicants and the genetic reservoir that is available. Breeding for nutritional improvement should also be related to the significance of the food crop as an economic source of key nutrients in the diet. Production practices need to be monitored for their implications for nutrient composition, since both improvement and reduction of such nutrients as protein and various mineral elements are known to be possible with alteration of some production practices.

Research programs to meet our various needs for data on food composition should be undertaken to guide our actions and commitments during the years ahead.

NUTRIENT REQUIREMENTS OF MAN

Rationale

The requirement of man for essential nutrients is the basis for establishing recommended levels of nutrient intake. The knowledge base for determination of recommended dietary allowances is surprisingly weak. To a considerable degree, the values for nutrient allowances currently used represent extrapolations to all ages from limited studies of healthy young adults. The numbers studied have generally been too small to provide a reasonable estimate of individual variation even for healthy young adults, and they make no adequate allowance for the special needs of individuals subject to stress from numerous factors of environment or disease, such as parasitic and other acute and chronic infections, extremes of temperature, activity, and such losses of essential nutrients as may occur through sweat from heavy physical work or high environmental temperatures.

There is an acute need for centers of nutrition research for evaluating the nutrient requirements of the healthy man. Emphasis should be placed, not only on societies prone to undernutrition, but also on the highly developed industrial society where qualitative changes related to sources of calories in the diet and general overconsumption can lead to widespread morbidity and mortality, as seen in heart disease, obesity, and similar conditions.

Emphasis should be placed on defining the minimum and optimum nutrient requirements for growth, pregnancy, and lactation in healthy and stressful situations, and on nutrient interactions and the effects of nutrient excesses.

Nutrient requirements must be defined and translated into terms that permit their use by those concerned with the food supply as well as those concerned with the health care of people.

FOOD INTERVENTION

Rationale

Food intervention programs should be designed to improve the nutritional status of the target population. Effective programs will be the outgrowth of data obtained from nutritional surveillance studies which have identified a potential nutritional risk to the target group. In addition, information concerning the food habits and food consumption patterns of the target group and factors which have an impact on the target group's behavior should be part of the analysis concerning the proposed method of intervention.

Several methods of nutritional intervention are in use today. Programs on food fortification, nutritional labeling, nutrition education, and supplemental feeding (such as food stamps, surplus food distribution, school lunches, and women and infant children feeding) are now being funded in excess of $6 billion annually. Little or no effective evaluation of the impact of these programs on the nutritional well-being of the target groups has been carried out. The cost-effectiveness of these programs versus other means of expanding purchasing power has not been evaluated for their relative impact on nutritional goals. As a consequence there is little information with which to assess the continuing value of these programs. The development of effective technology in areas of nutritional surveillance, food consumption, and food composition is a prerequisite to developing accurate evaluations of intervention programs. Similar considerations apply to international food aid programs carried out by the U.S., the European countries, and other developed countries. Little if any evaluation has been made of the nutritional impact on populations in developing countries.

Effective evaluation should be a built-in requirement of nutritional intervention programs. While many programs today specify that evaluations should be made, the support has not been provided for developing the necessary technology and for integrating the evaluation of the many current intervention programs. Are currently authorized food fortification programs effective? Should standards of identity or other regulations be changed to permit broader fortification of products which are significant sources of nutrients in the diet? Answers to these questions should guide government policies in food fortification programs.

Nutrition education programs today are fragmented and appear for the most part to be ineffective. Little effort has been devoted to determining the most effective period in the education of the individual to introduce sound nutritional concepts. Is this best done at preschool or elementary levels, or later in the educational cycle? What kind of training is required for nutrition education personnel? Before we can expect improvement in people's understanding of what constitutes sound nutrition, it is necessary to know more about effective educational intervention.

How effective in improving the nutritional standard of the recipients are food stamp and other food supplement programs or the international food aid programs? This information is woefully lacking. We may, in fact, find that current eligibility requirements or other factors are not properly established. Do these programs really provide nutritional benefits, or are they merely programs for income supplementation, with only random impact on the nutritional health of the individual? Technology for proper evaluation of these programs must be developed so that policy makers can use it in choosing between true nutritional supplementation and income support.

CONSTRAINTS

Rationale

Many factors have contributed to the persistence of malnutrition in the U.S., and constraints on the goal of abolishing malnutrition in the developing countries of the world are formidable. In both cases, malnutrition is most often due to maldistribution of existing food supplies, although famines continue to occur in limited populations due to local or regional crop failures. Inadequate purchasing power of low-income groups and inadequate knowledge of the essentials of a good diet are the limitations most often cited, but these in turn reflect economic and social policies which are not easily altered. Some specific constraints are discussed below.

1. Lack of education and training in nutrition

In the U.S., physicians, dentists, and other medical and public health workers, school teachers, and the general public receive little or no specific education or training in nutrition, and this pattern is replicated in the developing countries. At present nutrition information is most often provided by advertising and other commercial activities and oriented to the promotion of specific products or classes of products. Lack of knowledge as to the most effective period in a person's educational cycle to provide nutritional information and the qualifications of personnel required to provide this input represent a major constraint on our ability to make desired progress in the nutritional literacy of people.

2. Lack of opportunity for economic progress

In most developing countries, the lower socioeconomic groups are at an extreme disadvantage and often see little hope of economic progress. In the U.S., malnutrition still occurs most commonly among underprivileged groups, such as migrant laborers, American Indians, Chicanos, and urban blacks.

3. Lack of economic support

Federal and state support of nutrition education, training, and research is meager, and funds for adequate nutritional and dietary surveys on a national scale for nutrient surveillance have simply not been forthcoming. The USDA should have a strong intramural and extramural program in human nutrition. At present, only minor resources are allocated to this purpose. Research on food composition, the effects of food processing, and food safety are similarly grossly undersupported. While many current intervention programs require evaluation, support for the necessary technology to effectively accomplish this and to integrate the evaluation of the many supplemental programs now established is wholly inadequate.

4. Government policies

In the U.S., at local, state, or national levels, policy decisions are often made which have unrecognized or disregarded repercussions for human nutrition, and in developing countries nutritional considerations seldom enter into policy planning although food and nutrition can be shown to be essential aspects of national, social, and economic development.

For example, the sometimes arbitrary and inconsistent eligibility standards that may be established by the various governmental agencies involved for participation in supplemental food programs often result in denial of support to those in real need.

Similarly, priority should be given to the production of legumes, which are an essential supplemental part of the the diet of lower income people of the country, rather than to artificial support of the price of a basic crop like rice or sugar, where the net result would be a poorer diet.

In other instances environmental or safety regulations may require large expenditures of money for arbitrary levels of compliance where benefit relative to risk is minimal. The concept of zero tolerances for many chemicals places regulations on the basis of chemical analysis rather than on evaluation of potential risks versus benefits.

5. Political considerations

Much can be done to improve nutritional status where the political interest or will exists to do so. Conversely, decisions are often made for political reasons which have adverse repercussions on nutritional status. These may range from overly large foreign purchases or exports which raise domestic retail prices to ineffective and costly intervention programs continued for political reasons. Frequently artificial price supports for production of crops for export will generate foreign exchange without considering its impact on the diet of lower socioeconomic groups in the population. We need more analysis of and information about the trade-offs between production of food for domestic consumption and for export to enable decision makers to make regional agriculture policy decisions.

Food stamp eligibility rules may be changed to permit broader participation as a means of increasing effective income, not as a means of necessarily improving nutritional status. Once implemented, such programs are hard to change because of the political pressures associated with them.

6. Regulatory policies

Regulating agencies often set up unnecessary barriers to the development of more nutritious or lower cost foods because of their novelty, competition with traditional sources, culturally biased aesthetic judgments, technologically outmoded standards of identity, or simply failure to change anachronistic rulings to allow for advances in nutrition, food science, and technology.

Standards of identity for many foods are difficult to change even though improved nutritional content may result. The development of a high-protein macaroni, filled milks, restrictions on margarine which existed for years in many jurisdictions, and vitamin C fortification of fruit juices under standards of identity as a means of standardizing vitamin content are representative examples.

A carefully stated food and nutrition policy could provide a framework within which many of these constraints could be evaluated and, it is hoped, eliminated.

SECTION II: NATURAL RESOURCES BASE INPUT MANAGEMENT, AND THE ENVIRONMENT

INTRODUCTION

The immediate challenge for this nation--and indeed the world--is to optimize agricultural and other renewable resource productivity per unit of land area; per increment of water; per unit of energy, pesticide, and fertilizer input; and per unit of time. Not only is agriculture heavily dependent on climate and short-term variations in weather patterns, but the ability to produce more food is sharply influenced by natural resources of soil and water, and input management of energy, pesticides, and fertilizers. The management of these resources and inputs will have a major effect not only on food production but also on the quality of the environment.

Some estimates indicate that twice as much land may be physically available upon this earth for crop production than the 1.5 billion hectares currently used (Univ. of Cal. Task Force 1974). In addition, there are about 3.6 billion hectares of potential grazing land. Bringing new land into production requires expenditures of resources and labor, and some of the potentially arable land will be expensive to bring into production. We must carry out research on soil inventories, soil fertility tests, conservation of soil and water resources, and cropping systems if we intend to increase agricultural production with minimal damage to the environment. It is essential that we have an inventory of our soil resources so that we know how many hectares we have of land with high, medium, or low potential for producing crop and forage plants. This inventory is needed to provide the basic data for all future food and fiber production programs.

Besides land, water is another critical natural resource. Where it can be developed, irrigation offers a major opportunity to increase production. Of the 344 million hectares in the world that could be irrigated, only 200 million are currently irrigated (Univ. of Cal. Task Force 1974). In the U.S., 15 million hectares of land are irrigated. Areas of research concerned with use of the water resource for increased agricultural production include harvesting, reuse of water, water management, and water conservation practices.

Next to land and water, the basic and perhaps most fundamental determinant of agricultural production is the influence of weather and climate. The most efficient use of the weather and climate resource through weather data and forecasts and weather modification techniques should be a major goal of the agricultural sciences.

Since agriculture in its most productive form in the developed nations depends upon large quantities of energy, a major challenge is to reduce energy inputs into food production systems without jeopardizing productivity or energy output. Research areas include the quantification of energy requirements in the food and fiber system, low-energy substitutes for high-energy fertilizer, and conservation of energy on the farm, primarily from alternative crop production techniques.

Fertilizers have been a major factor in increasing yields over the past few years. Recent fertilizer shortages have intensified difficulties of expanding crop production, especially in developing countries. Another major factor in increasing yields is the wide variety of chemicals that has been used to protect plants and animals. The development of new nonpolluting chemicals which can be applied efficiently and in concert with biological and management control programs is of major importance for the protection of crops and livestock.

Even though there are great differences among nations in available resources, the basic technological data exist with which to make more effective use of resources to increase agricultural productivity. To do this, however, will require a thorough analysis and synthesis of *what is already known* about a specific natural resource and its management. Such state-of-the-art (or state-of-the-science) studies will need to be carefully planned and coordinated, and they should be supported with adequate funds and administrative commitment to insure their successful completion and implementation. Such studies should identify critical gaps in knowledge and point out research needs; they should also provide the knowledge basic to putting new or old agricultural management techniques into practice.

CHAPTER 7

LAND RESOURCE

RECOMMENDATIONS

1: Soil Resources Inventory. The soil resource inventory should be completed and should include laboratory characterization of key soil properties.

2: Interpretation and Use of Soil Resource Data. Studies should be undertaken on land suitability for differing types of agricultural production, irrigation potential, and fertilization needs, including forage management.

3: Soil Fertility Evaluation. Studies should be made of soil fertility and fertilizer needs for major crops on main soil types.

4: Conservation of Soil Resources. Research should be intensified on erosion control measures.

5: Farming Low Precipitation Areas for Maximum Production. Existing information on dryland farming systems should be mobilized, and research should be directed toward developing food crops and land management practices on lands where availability of water is the limiting factor.

6: Use and Management of Rangelands. A rangeland resource inventory should be made with sufficient detail to determine the potential carrying capacity of the different soils and to permit development of management strategies.

SOIL RESOURCES INVENTORY

Rationale

Estimates regarding the availability of land for future food production have been made by various scientists based on limited sources of data. To improve these basic data there is need for a systematic soil resource inventory to provide more specific information on the location and extent of the major kinds of soil and their potential to produce food and fiber. Such data must be supplemented by analyses of costs, markets, prices, and farm incomes. With such data and analyses, more accurate predictions can be made regarding the productive capacity of the different land areas of the U.S. to produce food and fiber. Interpretations based on the interaction of soil properties, soil slope, and climate provide the basic data needed in determining plant suitability, potential plant yields under alternative management systems, and the kinds of soil problems that limit yields. These data and analyses are essential for making realistic policy judgments regarding different ways of achieving needed production. They are also needed in locating those areas having the greatest potential for plant production and in determining priorities for development.

Modern soil surveys are available for about one-half of the U.S. There is need to synthesize all available data and to prepare basic soil maps of priority areas as a basis for developing programs for food and fiber production.

Implementation

A U.S. soil resource inventory should be complemented with soil maps and reports, and laboratory characterization of key soil properties. High priority areas should be updated where information is now obsolete.

Technology is known and available to carry out this task. The soil resource inventory can be implemented in a relatively short time through the employment of additional soil scientists and the use of remote sensing devices, computers, and other modern techniques. The USDA in cooperation with universities has the ability to do this work in the U.S.

INTERPRETATION AND USE OF SOIL RESOURCE DATA

Rationale

With a soil resource inventory, which would include soil maps, soil descriptions, and selected laboratory data, predictions could be made for best land use including various kinds of crops. By recording in an orderly manner types of soil, and yields and responses to management practices, it is possible to identify areas having high, moderate, and low potential for producing food and forage. These are some of the basic data needed for determining priorities for land development and application of specific soil and water management practices including drainage, irrigation, and range and pasture improvement. An assessment can then be made regarding fertilizer, irrigation and drainage needs, and cropping systems best suited for various levels of management. Information will be needed on laboratory analyses (chemical, physical, and mineralogical) of selected samples from benchmark soils and on field measurements to determine irrigation and drainage potential. We also need initial plot trials and field evaluations of fertilizer response by selected crops accompanied by greenhouse studies of nutrient deficiencies' response.

These activities are given high priority because of the their potential for most efficiently increasing productivity. Pre-development characterization of presently untilled lands should optimally require 2 to 10 percent of the total cost of bringing the land into crop production. Avoiding irrigation or drainage project failure and achieving high response from applied fertilizers and proper plant selection often result in avoided losses or increased returns several hundred times the cost of the research and development activities.

Implementation

Analysis and interpretation of existing soil maps and related resource data should be made to determine the suitability of land to types of farm, pasture, and range crops, irrigation and drainage potential, and fertilization needs. This analysis should include potential utility, productivity, economic and energy costs, and environmental impacts of bringing into production lands not now cultivated but classed as potential croplands. Irrigation needs, potential water resources, and energy costs of potential irrigation and drainage projects should be considered along with soil fertility-capability interpretations based on soil properties and projections of potential responsiveness to soil and water management practices, including added plant nutrients and lime. Attention should be given to lands now being farmed as well as to new lands. Soil maps and appropriate resource data also should be interpreted to show the potential for forage production under different levels of management, including reseeding, fertilization, brush control, and improved livestock management. In the U.S., soil maps should be interpreted to identify locations with greatest potential for agricultural production; and means (such as agricultural zoning) should be devised for retaining this land for agriculture. In the U.S., land resource data are now available in various forms. These data should be related to current land use and yields to determine the potential capacity of the U.S. to produce food and fibers.

SOIL FERTILITY EVALUATION

Rationale

More efficient and environmentally sound use of fertilizer is needed in view of fertilizer costs, energy requirements for its production, and potential "leakage" of nitrates from fertilized fields. Strict fertilizer needs should be determined for currently cropped lands and for lands earmarked for new crop production. Soil fertility evaluation systems, employing the development of uniform methods for the same kinds of soils and calibrated by field plot and greenhouse experiments, determine optimum plant nutrient requirements and fertilization procedures.

Implementation

Soil fertility evaluation should be made that includes an R&D program for reevaluation of soil tests for assessing plant nutrient needs ("soil testing") for major crops on principal soils so that fertilizers may be used more economically and with less environmental impact (especially through reduction of excessive use of nitrogen).

CONSERVATION OF SOIL RESOURCES

Rationale

As increased emphasis is placed on increased crop production to meet food needs, present cropland is likely to be cultivated more intensively, and new lands brought into crop production will frequently be more susceptible to water and wind/erosion than present cropland. As new lands are brought into production in the tropics, in moderate to high rainfall areas, soil erosion may be of increasing concern because of farmers' lack of knowledge about appropriate technology for erosion control.

Implementation

Soil conservation research in the U.S. should include refinements in wind and water erosion control measures to reduce sedimentation and to protect lands brought under cultivation with increased emphasis on crop production. Environmental protection considerations should include accelerated research in the U.S. on watershed modeling to protect water resources through control of nonpoint pollution from agricultural chemicals.

FARMING LOW PRECIPITATION AREAS FOR MAXIMUM PRODUCTION

Rationale

Insufficient rainfall on much of the cropland limits production. A major portion of such land cannot be irrigated because of inadequate water supplies, economic considerations, or other reasons. These soils present unique problems of management for sustained production. These soils are fragile and subject to wind and water erosion; and economic margins are small. Technological developments for application in rainfed agriculture in semi-arid areas are behind technology for production in more humid climates. Although these semi-arid areas presently support relatively sparse populations, population pressure may increase, and the productivity must be maintained and increased where possible. It is essential that increased effort be directed toward application of existing knowledge as well as development of new techniques and innovations in dry-land farming.

Implementation

Existing knowledge should be collected, synthesized, and mobilized to help increase food production in semi-arid areas. This should be a team effort of producers, research and extension workers, and government agencies backed by specific funds and administrative support. A major research effort should be directed toward developing adapted food crops and land management practices to improve and sustain production on land where water is the limiting factor and where irrigation is not possible. These studies should be conducted by teams of scientists representing many disciplines and designed to develop systems of land and crop management that will optimize food production from the land resource.

USE AND MANAGEMENT OF RANGELANDS

Rationale

Soil and climatic conditions in many areas of the U.S. dictate that much of the land be used for growing forage plants without cultivation. The area of nonarable but potential grazing lands is greater than the potentially arable land, because of restrictions imposed by topography, climate, or soil characteristics. The rangelands are both publicly and privately owned. The forage produced on these lands, most of which is harvested by grazing animals, constitutes an important part of the feed base for ruminant animals.

Rangelands are usually so fragile that mismanagement can quickly result in permanent damage to the resource and its productivity. A decrease in forage production on rangelands will decrease ruminant animal production or increase the need for feed grains for animal feed. Use of rangelands is sometimes restricted, because some range forages are deficient in minerals required by grazing animals and, in a few cases, levels of elements, such as selenium and molybdenum, may be so high as to be toxic to animals. Management methods should be developed to prevent problems caused by these and other deterrents to full use of range resources.

Implementation

Rangeland resource inventories and management strategies for rangelands are essential for use and maintenance of rangelands. The inventory should include all important physical features of the areas including the characteristics of the vegetation, and in sufficient detail for the determination of the potential carrying capacity of the different soils and for developing management strategies. Management plans should be made and implemented on public and private range lands to maintain the productivity of forage for grazing animals.

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CHAPTER 8

WATER RESOURCE

RECOMMENDATIONS

1: Cropping Systems. Emphasis should be given to research on cropping systems to optimize productivity with regard to water use.

2: Soil Water Management Systems. On-farm water management technology and systems should be devised that maintain optimal soil moisture in relation to other environmental factors for crops in all climatic zones.

3: Water Use in Non-Optimal Cropping Systems. The effectiveness of use of water in systems that are non-optimal for crop production should be improved.

4: Technology and Management for Water Supplies. Technology and management practices to increase and conserve water supplies for agricultural production should be devised.

5: Constraints on Water Management. Laws and regulations for management of water resources for agricultural production should be reviewed.

INTRODUCTION

Water is a basic renewable but limited resource. For the world as a whole it is a limiting factor in food production on more than 1.4 billion hectares of nonirrigated agricultural land and the major resource input that sustains production on approximately 0.16 billion hectares of irrigated cropland. Photosynthesis and transpiration are closely linked processes in the green plant-food production system. For a given crop, productivity varies directly with transpiration, other things being equal.

The U.S. water resource faces not only rapidly increasing demands from agriculture, but even more rapidly increasing demands from other sectors such as urbanization, industrialization, recreation, and environmental management. Increased efficiency of water use in agriculture suggests two kinds of strategies: (1) to provide and maintain an optimal supply to the crop root zone, and (2) to use the most effective cropping system available for productivity with a minimum of water use.

Water resource management strategies should be applied to all cropped areas. There are few if any places where water in the root zone is optimal (not too much or too little) at all times. Increasing the productivity of a unit of water is as important in the humid zones as in the arid regions. A unit of soil moisture from direct precipitation on a farm is potentially as important to agriculture as a unit supplied by irrigation.

Systematic research on crop systems in relation to water availability has not been done in any comprehensive sense. Systematic and comprehensive research at benchmark sites using indicator cultivar varieties could expand knowledge of crop systems and their interaction with water and reduce, or make more efficient, adaptive field trials.

Physical management to optimize soil moisture involves a cluster of management practices and technology. Depending on climate, weather, soil, and other factors, this may include a mix of irrigation, drainage, land farming, planting and tilling practices, and timing. Some new technological approaches as well as management practices offer promising prospects for maintaining optimal soil-moisture all or most of the time for many farming situations. Payoff from these approaches could be great.

Much of the time farmers must live with physical environments that are less than ideal but which cannot be corrected with reasonable economic measures. Examples are: shallow and sandy soils, poor macro-drainage, and inadequate water supply. There is a need to insure efficient use of water under these circumstances.

Precipitation around the globe varies widely both in total quantity and in seasonal distribution. Even the most humid regions suffer from moisture deficiencies during part of the growing season. Variability may pose a more difficult management problem than total supply. Agriculture suffers from some kinds of water deficiencies in all parts of the U.S. Improving water supply includes: (a) storing water otherwise wasted in runoff to the sea, (b) using groundwater to increase total supply or to provide supplies congruent with crop needs, (c) providing macro-drainage so that excess water can readily be removed, (d) conserving rainfall on the farm, and (e) harvesting water by watershed management techniques. Quality is an important and neglected element of water supply; which is really measured by the amount of water of usable quality available at a given time. Water supply improvement beyond the limits of the farm requires collective action, and therefore social and political considerations become important.

As mentioned earlier, institutions have important effects on agricultural water management. Principal institutions which both enhance and constrain efficient water management include law, organizations for managing and distributing water supplies, state and federal agencies, and marketing systems.

There is a great store of knowledge and information about agricultural water management that is not being used. In the final analysis good water management systems and practices are site-specific. Besides vigorous research, every effort needs to be made to bring the current state of knowledge to bear on at least the critical problems.

Pervasive as it is in occurrence, fresh water is nevertheless a scarce resource which is growing scarcer. Its quantity is generally renewable, but its quality may not be. About 4,200 billion gallons of water per day fall on the conterminous United States; 3,000 billion gallons per day evaporate or transpire, mostly by crops or forests. Grain crops alone probably transpire nearly 100 billion gallons per day. Bradley (1962) points out that a pound of bread and a pound of meat per day require 3,000 gallons per capita per day, or, for 200 million people, 600 billion gallons of fresh water daily. The water budget rather than land may really place the more limiting constraint on food supply. Water consumption by irrigated agriculture was estimated to be about 75 billion gallons per day, or 89 percent of all consumptive use and about 59 percent of the total water withdrawn in 1970. According to the U.S. Water Resources Council (1968), irrigation will constitute only about 19 percent of withdrawals by the year 2000, but will account for about 70 percent of consumptive use.

CROPPING SYSTEMS

If a cropping system is to be optimized with regard to water supply, more needs to be known about productivity of crops as related to their water regimes. Given desirable cultivars, comprehensive experiments in which more complete and relevant sets of production factors are controlled or measured should be conducted. Few, if any, such experiments have been made. Major benchmark cultivars should be used and experiments designed and instrumented to insure comprehensive intimate environmental information, including weather. The variance due to water stressing at various moisture levels should be evaluated. To achieve the desired results, a comprehensive and systematic experimental approach is needed rather than just adaptive field testing. This will significantly reduce the time required to get results. Even 5 to 10 years of adaptive testing at a single site does not give a good climatic sample. Repeating a comprehensive study at several benchmark sites can add significantly to the total climatic information and provide for better selection of cultivars and other production inputs. A serious deficiency in past cultivar and variety testing is that phenological history has not been recorded. There is a strong interactive relationship between phenological stage and soil moisture and temperature.

The experimental approach should also include productivity response of various cultivars to production factors at optimum soil moisture conditions in addition to measurement and evaluation of the prevailing specific site moisture regime.

Benchmark genetic cultivars can be used so that the large number of commercially available strains need not be individually tested. Relating known genetic makeup of cultivars to pertinent environmental variables will markedly improve the ease with which technology can be transferred from one region or country to another.

SOIL WATER MANAGEMENT SYSTEMS

Emphasis should be placed on developing technologies that involve total agricultural water management aimed at providing delivery of water to the crop root zone when it is needed by the crop, or in removing water from the root zone when it is in excess.

In the past, the practices of irrigation and drainage have been largely considered separately. Water management for optimal moisture conditions for crop growth requires that they be considered together.

Land surface modification is an important consideration in both removing excess water and attaining efficient irrigation. Timeliness is perhaps one of the most critical items in the production process from the standpoint of both drought and excess water on the land.

Scheduling of irrigation based on environmental factors holds great promise in determining the frequency and amounts of application to meet crop needs quite independent of the irrigation method. Computerized techniques provide the capability for rapid evaluation of crop needs and rapid mass distribution of management decisions relative to both water and fertilizer applications.

Combined irrigation and drainage systems coupled with instrumentation for moisture-sensing feedback offers real potential for high frequency optimal soil moisture control.

Optimizing with respect to soil moisture for different soils, climates, topographies, and similar factors shows great promise for expanding the land resource base for certain crops as well as increasing yields.

Energy requirements as well as cost will be an increasingly important consideration in the development of effective water management systems throughout the world.

A major problem of wet soil is its resistance to traffic and the constraints this places on planting and other farming operations on the land. Strategies should be researched which will reduce the need to till or get on the land with heavy equipment. These will not only improve operation efficiency, but will reduce both sheet erosion and costs. Soils are often overdrained in order to permit traffic in the wet season, and valuable water needed at later critical times is lost.

Another objective of water management on the farm is to conserve nutrients in the soil and reduce the return of salts and the erosion of soil and sediment to rivers, streams, and lakes. This objective is important in part because of specific quality and emission standards enforced or to be enforced under the National Environmental Protection Act.

Irrigation and drainage practices, especially under arid conditions, have a direct bearing on the salinity and sodium of agricultural lands. Crop production is seriously limited in many areas of the U.S. as elsewhere in the world by excess salts or high sodium soils. In addition to the relation of water quality and soil salinity to crop yields, the water management region has an important effect on the quality of return flows and the amount of salts returned to river systems.

There is strong experimental and theoretical basis for the possibility of precipitating salts in the soil profile and thus rendering them harmless to crops. Salts thus precipitated are immobilized and kept from returning to the water supply of the river system. The key to this process appears to lie with the ability to adequately control irrigation and reduce the leaching fraction to a low level. The potential for conserving water through improved practices and the benefits to be derived from reducing the salinity hazard deserves evaluation in various arid regions.

Implementation

The technology for various irrigation and drainage systems has reached a relatively advanced stage. New developments have been made in surface irrigation, sprinkler irrigation, trickle irrigation and open ditches, and in tile and corrugated plastic drain tubes and well drainage. There are many promising avenues that should be researched under a wide variety of site conditions. In order to achieve efficiency and coordination of effort, new or existing centers of excellence in several geographical areas should be given adequate support.

WATER UTILIZATION IN NON-OPTIMAL CROPPING SYSTEMS

Agriculture will always be faced with physical conditions that are not optimal--and in some cases substantially less than optimal--as far as water management is concerned. The following deals with some of the most pervasive and difficult conditions under the assumption that it will be desirable to keep some of the land characterized by such conditions under production and to insure some reasonable economic return to the farmers.

Low Quality Supplies

Salinity may inhibit plant growth at levels as low as several hundred parts per million (ppm) in the water supply under poor management conditions. On the other hand, with optimal conditions, economic crops may be grown with water supply concentrations as high as 5,000 to 6,000 ppm. As river systems are used, salinity concentration will increase upstream to downstream. Large reserves of groundwater are also saline. Both situations exist, not only in the U.S., but all over the world, and effective use should be made of them. Two approaches are needed. One is to develop cultivars that are increasingly salt tolerant. This approach has been touched only barely and deserves increased effort, possibly at a national or international center. The other approach is through management on the farm involving irrigation and drainage practices that reduce or control osmotic stress, prevent adverse ion adsorptions, and involve appropriate tillage and other cultural practices to reduce salt crusting and insure germination. Much is already known about management of low quality waters so that this may largely involve adaptation to specific sites. Some experimentation needs to be continued on management practices, however.

Severe Irrigation Water Shortage

Climate and weather variation is great, especially in arid lands, and strategies need to be devised which take into account risks and benefits. This is an area where improved weather forecasting and and more drought resistant crop varieties would be useful. (See Chapter 10, The Climate and Weather Resource.)

Soils with Low Water-Holding Capacity

Soils with low water-holding capacity include extremely sandy soils and shallow soils. In most cases, frequent irrigation is the obvious solution, and some specialized irrigation technology has already been developed that is useful for maintaining a satisfactory soil-water regime. Most cases may simply require application of available technology, but consideration should be given to the need for research on this topic.

Drought Hazard

Drought is a major hazard to agriculture. Ability to predict climate and weather on a long-range basis would be extremely useful in managing drought-prone areas. Many of these areas are grazed, and information on climate and weather variability is needed to design management strategies for grazing.

TECHNOLOGY AND MANAGEMENT FOR WATER SUPPLIES

Efficient water management on the farm may often be impaired or rendered useless because of conditions beyond the farm boundary. This is particularly true where irrigation and drainage are required. In these cases the system is beyond the control of the farmer and dependent upon common action at some level of society. Farmers may, however, be able to conserve moisture on their own cultivated lands or on watersheds under their control.

Storage of surface water in reservoirs is the principal approach to insuring supplies during dry periods whether the farms lie in the arid western U.S. or the humid regions of monsoon Asia. Engineering technology for providing such storage is well advanced, but primarily in arid lands. Increased attention needs to be given to improved technology and management practices for storage reservoirs, particularly for smaller reservoirs in sub-humid and humid regions. This is both an engineering problem (adequate and safe structures) and a hydrological one (optimal amount of storage under conditions of stochastic and spatial variation).

Groundwater reservoirs contain a vast amount of water in storage. These may be used to stabilize supplies from other sources in much the same way as surface reservoirs, but they may also be withdrawn at greater rates than they are replenished. The High Plains of Texas is a primary example of groundwater mining. Well technology and methods for assessment of aquifer potential and for recharge should be improved.

Perhaps one of the major reasons for inefficiency of irrigation is inadequate systems for distribution of water to farmers in the right amount at the right time. This problem is often partly social and, in regions that are highly developed and where units are small, poses serious right-of-way problems. Research is needed to produce more effective arrangements and design, control and measuring structures and use of new materials, particularly inexpensive enclosed conduits.

A nation's or region's water supply is really measured by the amount of water of adequate quality available to meet needs at any given time. Increasing or enhancing our supply through improvement or safeguarding its quality can pay large dividends. Reuse of municipal and industrial waters has not been practiced extensively in agriculture because of uncertainty regarding the fate of bacteria and viruses and the long-term impact of various heavy metals and nutrients on soils. Research should be directed toward reenhancing these waters and reusing them either directly or through groundwater recharge.

Conservation of water supplies in surface reservoirs, in the soil, or through water harvesting is of great importance. Little practical progress has been made in reducing surface evaporation from reservoirs. The use of monomolecular layers or some other surface covering, especially on small reservoirs, needs further exploration (Hughes et al. 1974). Recent preliminary computations indicate that turning over the stratified levels of deep reservoirs using air or some other means to bring this cool water to the reservoir surface could substantially reduce evaporation. More emphasis needs to be given to conserving soil moisture by tillage, by ground covering, or by modification of micrometeorology using windbreaks or shelters, especially in semi-arid plains regions. Intercropping appears to be one of the more effective ways to modify micrometeorology. This approach has had very little attention.

Water harvesting, i.e., increasing runoff by changing the surface infiltration or plant cover, is a promising means for increasing surface supplies. Runoff farming, a process that accumulates sufficient water from a large area onto a contiguous small one, has been practiced for centuries. Increasing attention needs to be given to improved materials and methods of water harvesting. There are a number of relatively simple ways to conserve water that could be easily implemented in arid lands around the world (NAS 1974). Finally, weather modification by cloud seeding to enhance precipitation could enhance water supplies by adding soil moisture and increasing runoff. (See Chapter 10, The Climate and Weather Resource.)

The water regime of rangelands is a major element in livestock production. There is potential for significant improvement in the availability of drinking water for animals. Water harvesting research should be aimed at capturing and concentrating water to allow animals to secure water but spatially distributed so as to minimize both animal travel and the excessive trampling of feed near the water hole.

A second area of increased production potential on rangelands is in the selection and/or breeding of both grasses and shrubs that are palatable, nutritive, and water efficient for the water regimes typical of rangelands.

CONSTRAINTS ON WATER MANAGEMENT

Improving efficiency of irrigation water use may be limited by institutional arrangements, including water rights laws and their administration. In most of the western states public waters may be appropriated as private use rights if diligence is exercised in constructing works and the waters are used beneficially. Priority of rights is based on time of filing, but great leniency has been exercised in proof of diligence and in regard to efficient use. Normally water rights may be transferred by purchase and sale if the public interest is not impaired. Even so, water-rights laws and their administration are highly complex, and research is needed to consider what changes should be made to foster greater efficiency. This is especially true considering increased competition by energy development and urbanization for water supplies. Laws governing groundwater are often inconsistent with surface water laws. A different, and often poorly related, legal approach is being taken to water quality. The legal basis for irrigation water rights in the sub-humid and humid states is at a less developed stage than in the arid West. Attention needs to be given to how laws and regulations might be improved to encourage efficient use of water and insure its availability for agriculture insofar as possible. Laws relating to water quality need to be formulated realistically so that efficient agricultural practices are not constrained more than is socially desirable.

Laws are only one element in the institutional arrangements concerned with water. Organizations for delivering water and their rules, regulations, and pricing arrangements represent another major class of institutions whose operations have significant bearing on efficient management of water supplies. Other important examples include the process of public planning and decision making with regard to water systems and related land use, the structure and role of federal and state agencies, and the water market. We need greater understanding of how these institutional processes and laws and regulations can be improved.

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CHAPTER 9

FERTILIZER RESOURCE

RECOMMENDATIONS

1: Efficient Fertilizer Use. Studies should be implemented on improving the efficiency of fertilizer nutrient use.

2: Programs for Heavily Fertilized Soils. Phosphate and potash fertilizer programs should be developed for heavily fertilized soils.

3: Ammonia. Technology to produce ammonia from coal should be developed.

4: Phosphate Rock. Studies should be made of more efficient extraction of phosphates for fertilizers.

INTRODUCTION

Fertilizer is essential in maintaining or increasing food production. Fertilizer is needed to help developing countries in their struggle for food self-sufficiency. And it is needed in increasing quantities in developed nations to sustain production and to produce surplus food which can be shared (Nelson, in press).

Worldwide interest in fertilizer has intensified as its role in food production has become better understood. Estimates generally indicate that 30 to 40 percent of the increased agricultural production in this country during recent years is directly attributable to increased use of fertilizer. In developing countries, where soils are less fertile, fertilizers can be even more important, expecially on crops of high yield potential. On the average, 1 kilogram (kg) of nutrients increases rice yields 10 kg and wheat 8 kg in developing countries. Improved varieties give even greater returns.

However, fertilizers alone--without use of improved cultural practices--can increase production only modestly, if at all. There seems to be little doubt that our ability to feed ourselves depends in considerable part on how abundantly we can make more efficient and reasonably priced fertilizers available to the world's farmers.

Fertilizer technology research and development in the U.S. is conducted largely by the Tennessee Valley Authority (TVA) at its National Fertilizer Development Center. The U.S. fertilizer industry conducts very little research on its own. Recently, an International Fertilizer Development Center (a nonprofit organization entirely separate from TVA) has been set up at Muscle Shoals, Alabama, to develop technology specific to the needs of developing countries. The USDA and the land grant universities traditionally have conducted research on fertilizer use, soil testing, and similar studies, but in recent years their research effort on fertilizers has decreased.

In general, the level of fertilizer technology in the U.S. is high, possibly leading the world. New problems of major importance, however, have risen in the last couple of years which demand immediate attention and are included in the above recommendations. First, until very recently fertilizers have been in short supply and are high in price in the U.S. and worldwide, indicating the need for developing ways to use fertilizers more efficiently. Recommendations 1 and 2 deal specifically with this. Second, shortages of raw materials needed in fertilizer manufacture have developed, particularly natural gas for ammonia synthesis (see Recommendations 3 and 4). Third, a great concern has developed about food shortages in developing countries, coupled with the fact that the major input, fertilizer, has been developed solely to meet the needs of temperate zone soil and crops. These problems are critical, and to solve them will require funding the R&D effort at a higher level than in the past.

EFFICIENT FERTILIZER USE

Rationale

A worldwide problem is the low recovery of fertilizer nutrients by plants--usually averaging only about 50 percent of the applied nitrogen and 30 percent or less of the applied phosphate. Losses may be even greater on certain tropical and subtropical soils. There is strong evidence suggested by TVA that recovery and efficiency can be improved by coating nitrogen fertilizers to impart slow-release properties (such as sulfur-coated urea) and by using improved application methods and timing.

There is a real need to develop and install methods and soil management practices involving alternatives to inorganic sources of nitrogen such as legumes in crop sequences or as cover crops and organic sources such as animal and human wastes. (See Chapter 11, Energy Resource.)

This is a high priority problem. A 10 percent increase in nitrogen efficiency, which might be easily achieved, would save the world nearly 4 million tons of nitrogen--the nitrogen input for 40 million tons of cereals. In addition, more efficient use means less nitrogen lost through leaching into groundwaters thus improving the environment.

Implementation

A concerted, immediate research effort is called for. Stable nitrogen isotopes and radioactive phosphorus, both available, should be used. Field and laboratory investigations and, probably, construction of pilot plants to produce new fertilizers would be required.

PROGRAMS FOR HEAVILY FERTILIZED SOILS

Rationale

Large residual reserves of phosphorus and potassium build up in soils that have been heavily fertilized. U.S. farmers tend to continue heavy fertilization, presumably resulting in inefficient fertilizer use. Field experiments, coordinated with soil tests, need to be conducted to determine whether phosphate and potash use can be safely reduced without endangering crop yields and, if so, how much and under what conditions. Considerable fertilizer might be saved for use elsewhere, besides decreasing fertilizer costs to the farmer.

This is a major problem in the U.S. and industrial countries. In the U.S., for example, about 40 percent of soil tests indicate that high fertility conditions exist. However, there is some reason to doubt whether soil tests adequately measure the nutrients available to plants under today's high fertility agriculture.

The U.S. uses about 4.6 million metric tons of P_2O_5 in phosphate fertilizer, and 4.5 million of K_2O in potassium fertilizer. Possibly 20 percent of this fertilizer is used on soils where it is not needed. Saving this amount of costly fertilizer would be of considerable monetary benefit to the U.S. farmer and would release U.S. produced phosphate to world trade and improve the balance of payments (the U.S. is a large net importer of K_2O).

Implementation

A research effort involving field research on this problem has already been started by TVA and the land grant universities, and it should be quickly expanded.

AMMONIA

Rationale

Essentially all U.S. ammonia production is based on natural gas as a feedstock. The U.S. does not now produce sufficient natural gas to meet demand, and the projection is that the shortage will increase. Fuel oil or naphtha can be used to produce ammonia instead of natural gas, but the U.S. is also short of these.

Obtaining hydrogen or methane from coal is an alternative process. Several developmental projects related to coal gasification are underway in the U.S.; however, these projects will not produce a gas suitable for ammonia production. Proprietary German technology is available that will permit ammonia production, but the processes need considerable improvement and are extremely costly to install and operate. New, modern technology available to the U.S. and developing countries is badly needed.

Since U.S. coal reserves are abundant, the development of an efficient means for producing ammonia feedstock from coal is seen as a practical necessity. The development, optimization, and demonstration of this technology for U.S. coals is expected to be expensive and may require up to 10 years.

With the current and pending situation on natural gas and petroleum-derived feedstocks worldwide, there is no choice but to go to coal. In fact, the future of the world food situation may hinge upon developing low cost and adequate technology using coal as a feedstock for ammonia synthesis.

Implementation

The problem would have to be attacked by a large, chemical and engineering oriented organization such as TVA.

PHOSPHATE ROCK

Rationale

Phosphate rock is the sole source of phosphates for fertilizers. Currently, there are only a few major phosphate ore reserves in the world which are mineable. New deposits, mostly low grade and marginal in nature, are being found around the world, many in developing countries. Essentially there are two problems with the use of phosphate rock.

1. Mining Recovery

Currently, only 40 to 60 percent of the phosphate in ore is recovered in mining operations. Phosphate in slimes discarded in the washing operations probably is irretrievably lost, and in addition slimes present a difficult environmental problem.

Research is needed to identify the chemical and mineralogical composition of slimes, to determine how to recover more phosphate during washing, and to determine ways to dehydrate remaining residues so that they will solidify and not cause environmental difficulties.

2. Marginal and Low-grade Ores

High-grade ores in Florida are being exhausted rapidly: their life is expected to be only around 30 more years. Many countries, including developing countries, have deposits of low-grade ores not now considered mineable because of their low phosphate content and undesirable mineral properties. Ways need to be found by which these lower grade ores can be used either through beneficiation or chemical processes.

Implementation

There is some research in this area contemplated by TVA and the International Fertilizer Development Center. This is a high priority problem, and chances for its solution are good.

Solving the problem would extend the life of the Florida deposit possibly for another 20 years and would be of great value to many developing countries in that they could use their own lower grade ores rather than buy high-priced ores on the world market. Research strategy would involve laboratory studies of deposits, beneficiation tests, and a pilot plant.

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CHAPTER 10

THE CLIMATIC AND WEATHER RESOURCE

RECOMMENDATIONS

1: Weather Information. A weather advisory system should be established to provide weather information, including seasonal and longer term forecasts, for the efficient management of the agricultural enterprise.

2: Impacts of Weather Variability and Climatic Fluctuations. Field studies and statistical studies should be initiated on the impact of weather and climate fluctuations on food, water, and energy supplies.

3: Weather Modification. Research should be intensified to determine the necessary atmospheric properties for rainfall augmentation and hail suppression on agricultural and forest lands.

INTRODUCTION

The atmosphere's reservoir of oxygen, carbon dioxide, and gaseous water provides life support to biological systems. The motion or circulation of air provides the mechanisms for cycling and transporting the water vapor, carbon dioxide, and other gases. The biological systems are driven by the solar radiation penetrating the atmosphere.

Many atmospheric properties are important elements in food production. Temperature controls the speed of biological reactions. High humidities favor crop diseases and insects: for example, in 1971 a serious leaf blight attacked the corn crop as a result of high humidities throughout the central U.S. Atmospheric moisture also affects the quality of grain during harvest and storage. Atmospheric turbidity and cloudiness determine the amount of solar energy reaching the plant canopy. Perhaps the most important contribution of weather to food production is its effect on the balance of water between the supply from rain and the demand from evapotranspiration. The droughts of the thirties and fifties and more recently in 1974 brought widespread damage to major food producing regions of the Midwest. Although excess water at planting and harvesting times has an adverse effect on field operations, for most agricultural systems the availability of water during critical periods of the growing season increases the chances of an abundant harvest.

WEATHER INFORMATION

Rationale

The system for agricultural production in America and other major granary regions has become more complex with improved agricultural technology. The increased use of fertilizers, high potential genetic stocks, and mechanization has produced management systems requiring more sophisticated strategies for operating the farm. These management systems are more sensitive to weather events than the simpler schemes of other areas. The farm investment in mechanized agriculture must fit the climatic conditions of the area. Day-to-day decisions by farm managers require correct interpretation of short-range weather outlooks.

Changing climate and fluctuating weather add a further complication to the impact of weather on the farm enterprise. The selection of alternatives in long-term investments (20 to 30 years payoff) should include evaluations of climatic trends, the possibility of the nonrandom character of weather events (such as drought), and variabilities in weather (such as rainfall and temperature).

Some of these farm operations involve environmental issues. Examples of major farm decisions sensitive to weather can be cited.

1. Day-to-day operational decisions by farm managers for immediate management of planting (soil temperatures), harvesting (grain moisture content), other crop and animal production, and the marketing and storage of farm products require critical and timely weather information. Specialized services providing "real time" weather information and forecasts are required throughout the year.
2. The design and operation of efficient pest management systems rely on accurate interpretation of the micrometeorological conditions favoring weed, spore, or insect development and the dispersion of pesticides into a turbulent atmosphere.
3. Hydrologic systems for handling feedlot waste are based on the climatic expectance of intense rainfall.
4. The availability of solar energy for the drying of fields, drying hay or grain, and human or animal protection is related to weather conditions. Energy from wind is also an attractive alternate energy source on farms.
5. The design and operation of water management systems depends on proper interpretations of short-range weather outlooks. Capacity and operation of an effective irrigation system depend on the climate assessment and short-range weather forecasts.

6. The design and operations of hay and grain drying facilities require information concerning humidity, temperature, and other weather events.

The nationwide program providing weather information to agriculture both increases production, conserves energy, and reduces crop and livestock losses. In June 1975 a special panel of the Agricultural Research Institute reaffirmed an earlier position that crop and livestock losses could be minimized by increasing and improving weather forecasting services to farmers. The program would reduce the hazards of pollution by promoting a proper design of pest management and hydrologic systems.

Implementation

A system for specialized weather services for agriculture is required to increase production, improve efficiency, and limit environmental hazards. The system would draw on the reservoir of knowledge, current research, available climatic data, and weather forecasts.

This program should include implementation of the provisions of the current federal plan for improved weather services to agriculture, with immediate expansion to nationwide coverage of the agricultural forecasting program of the National Weather Service. Responsibility for information dissemination and adult education for farmers resides in the USDA and its state cooperators. The Cooperative Extension Service is the best information distribution agency for agriculture. This extension program will provide liaison support with the service offices of the National Weather Service. Although the extension program will support the Agricultural Meteorological Service offices, where they exist, the implementation could proceed prior to the completion of the nationwide agricultural program by the National Weather Service.

IMPACTS OF WEATHER VARIABILITY AND CLIMATIC FLUCTUATIONS

Rationale

Much has been said about the recent trends in climate. There is well documented evidence that warming of the polar and mid-latitudes occurred during the first half of this century, and these same areas have been cooling since the early 1940s. Associated with these recent trends, many of the northern agricultural areas have experienced cooler summers, shorter growing seasons, and lower moisture demand. It is not certain that the decline in temperatures will continue; the decline may halt or reverse itself. However, one of the risks in food production is the variable and fluctuating character of climate. Additional evidence indicates that seasonal rain has decreased in many tropical areas. In other regions of the world, a more favorable rainfall pattern may have occurred. The year-to-year and seasonal variations in rainfall provide a major impact on plant growth and development.

Implementation

The effects of fluctuating climate and weather on agricultural production should be determined. The current evaluation technique involves correlation between historical yields and concurrent weather events. These statistical studies are providing a general relationship for predicting the effects of weather on the yields. To estimate the impact of the variable climate and weather on food production, contingency studies using the climatic information from the historical data bank will be necessary.

To further sharpen the estimates of yields from weather information, field experiments designed to specifically study weather/crop yield relationships must be undertaken. Since these experiments must focus on the water balance at critical stages of plant development, the experimental design must provide varying water stress during these periods for crops grown under current technological development.

The use of earth resource satellites for assessing worldwide crop conditions is being studied through the Large Area Crop Inventory Experiment (LACIE). LACIE will provide a critical assessment of the potential for using satellites in evaluating the world's food production.

WEATHER MODIFICATION

Rationale

Weather modification for the purpose of augmenting natural rainfall has been practiced in the Western U.S., the Great Plains, and the U.S.S.R. for more than 25 years (NAS 1973). Results from the cloud seeding activities have been both promising and disappointing. Some experiments have reported increases of 10 to 20 percent above the natural rainfall. Many modification programs have not provided a demonstrable change in rainfall; while others, notably the Whitetop Experiment in Missouri in the early 1960s, have experienced less rain in the seeded areas. There have been several reports of significant increase in snow packs from winter seeding in mountain regions.

The reduction of the intensity, size, and frequency of hail storms through cloud seeding offers an additional component to weather modification. In selected agricultural areas reduction of hail damage to crops is a significant economic goal. Many cloud physicists and experimentalists are confident that weather modification technology for hail abatement is either currently available or will become usable within the present decade. The return from the development of a dependable cloud seeding technology for rain augmentation and/or hail abatement will be great. The benefits were enumerated in the report on "A National Program of Research for Weather Modification" of the joint Task Force of the USDA and State Universities and Land Grant Colleges released in 1968. The gain to agriculture will be from the prospect of stabilizing the water supply for agriculture and the promise of hail abatement. Since the cost of seeding clouds is small compared to other inputs to the agricultural enterprise, the economic importance of a dependable system could be extremely valuable. It appears that not enough is now known about the optimum microphysical conditions of the cloud or of the stability properties of the atmosphere in which the cloud is imbedded to project success or failure of a seeding operation.

Implementation

In some limited applications implementation of the technology of weather modification can responsibly start now. For most uses, additional research in cloud physics and cumulus dynamics is required before the full potential of weather modification will be realized. In addition to laboratory experiments, major field trials are still required. High priority should be given to field experiments in the High Plains (rain augmentation and hail suppression) and in the midwestern and southeastern U.S. for convective clouds in summer. Existing research groups, such as the National Center for Atmospheric Research, the Bureau of Reclamation, and the atmospheric science laboratories of the major universities, should be assigned responsibility for this research.

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CHAPTER 11

ENERGY RESOURCE

RECOMMENDATIONS

1: Energy Flows. Studies should be undertaken to determine and characterize the types of energy flows throughout the system of production, processing and distribution, and utilization of our food and feeds.

2: Substitutes for Nitrogen Fertilizers. Research is needed for developing effective and economical substitutes for commercial nitrogen fertilizers, such as animal wastes, legumes and green manures, and sewage sludge.

3: Conservation of Energy. Management programs should be developed to conserve energy on the farm.

INTRODUCTION

Energy--like land and water--is a vital resource in food production. The U.S. food system (production, processing, distribution, and preparation) uses from 12 to 15 percent of our annual energy budget. With the availability of an abundant supply of relatively low cost energy, the U.S. food system has become energy intensive. The application of energy has focused on increased unit productivity on our farms and ranches, the supply of a wide spectrum of wholesome and nutritious consumer products, and the release of a major portion of our population from menial, tedious, and economically unrewarding tasks.

Of the energy currently being used in the U.S. food system, it is estimated that one-third is used for production, one-third for processing, and one-third for preparation and distribution. The quantification of the forms of energy used by the major operations of the system would permit identification of the substitutability of more abundant forms of energy for the nonrenewable short supply energy forms currently being used. The characterization of the energy use would help to identify relationships between energy inputs and the quantity and nutritive values of the outputs, thereby providing opportunities to conserve energy and develop alternative practices.

The pressure of human population on land, energy, and water resources is now greater than it has ever been before. Man's use of energy to manipulate and manage his environment is probably the most significant factor in the rapid growth of the human population. The exponential increase of human numbers directly coincides with the use of fossil energy. In particular, energy has been used to reduce human death rates by effective public health measures and to supply the food needed by an increasing population.

Energy and food are in short supply today primarily for the same reason--the growing number of human beings. It is interesting as well as significant that energy use has been increasing faster than world population. The U.S. population doubled in the past 60 years, but our energy consumption doubled in the past 20 years; the world population doubled in the past 30 years, but the world's energy consumption doubled in the past decade.

Because most of the energy is being supplied by nonrenewable resources, fossil energy reserves are rapidly disappearing (Figure 1). Known world reserves of petroleum and natural gas are expected to be more than half depleted in the next 25 years (year 2000), and more than half of the coal reserves are estimated to be depleted about the year 2100--shortly before the world reaches its projected maximum population density in the year 2135.

While the recently expanded efforts to find new reserves of petroleum fuels and to develop new energy technologies to permit use of more abundant forms of energy will help to alleviate the short supply of energy, opportunities exist for obtaining information to provide a basis for: assessing the impact of national policies on the food production system; determining the effects of conservation and/or alternative practices on energy use; and establishing long-range research priorities with the greatest potential for increasing the effective use of energy resources for food production.

ENERGY FLOWS

Rationale

Production, processing, distribution, and consumption of food for the sustenance of the people of the U.S. require high levels of energy subsidy. Improved species, varieties, cultural practices, and management have been contributing factors to our successful production system; however, all are dependent on the ever increasing energy applied to the total system.

The dependence of the national food system on abundant, low-cost sources of energy has created a high level of vulnerability to severe disruptions when energy supplies are curtailed and there are sharp increases in the prices. Fuel

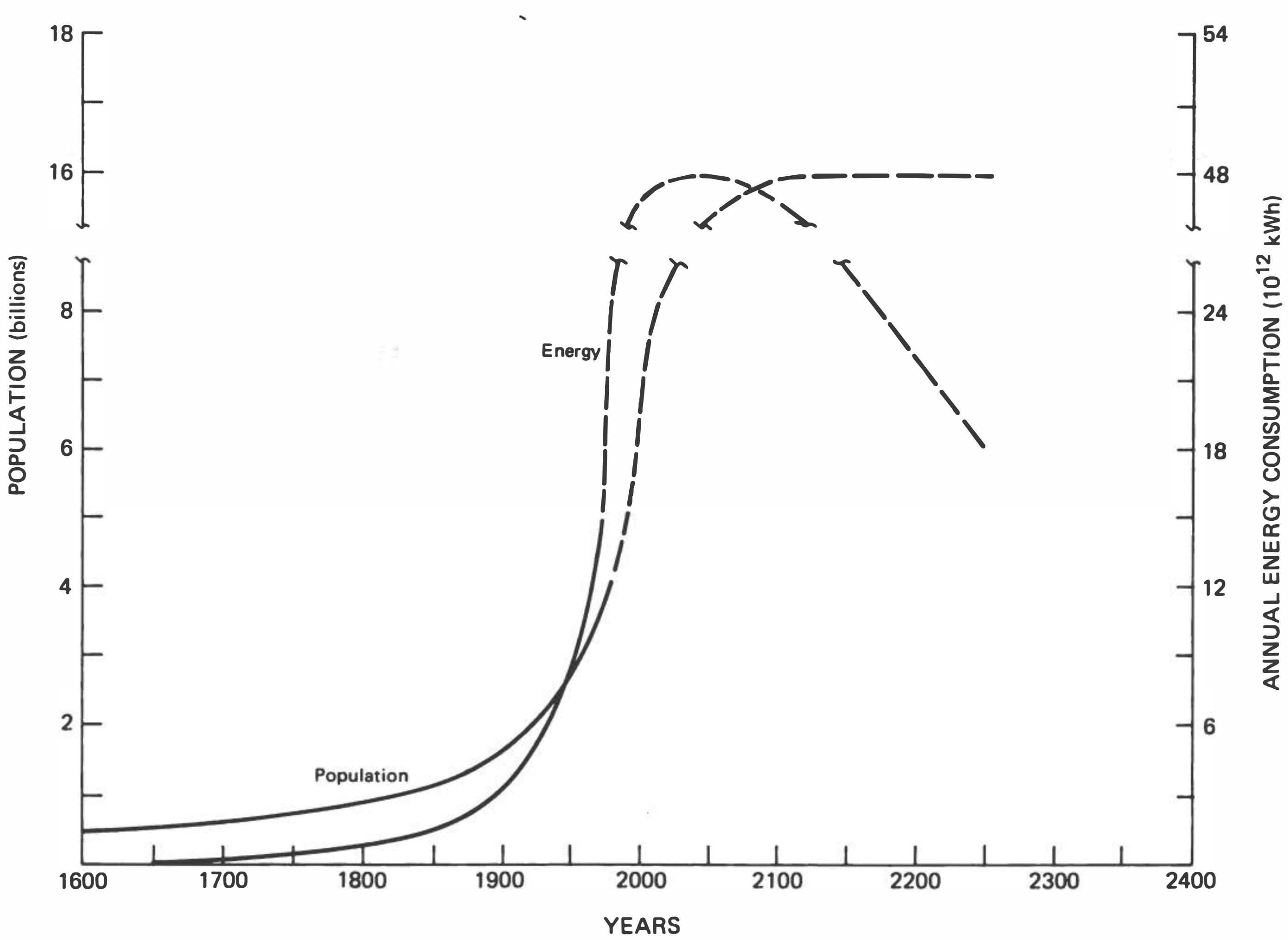

FIGURE 1 Population and fossil fuel consumption. Estimated world population numbers (———) from 1600 to 1975 and projected numbers (— — —) to the year 2250 (Freedman and Berelson, 1974; NAS, 1971; UN, 1973). Estimated fossil fuel consumption (———) from 1650 to 1975 and projected (— — —) to the year 2250 (Hubbert, 1972).

shortages may be catastrophic to the system as was demonstrated in Iowa in 1973 when insufficient LP gas for drying the crop caused delay of harvest and a loss that at one time was estimated to be as much as 10 million bushels.

Although the national system has become highly dependent on abundant, low-priced sources of energy, the consumption patterns within each segment of the system, while extremely critical, are not well known. Even the total magnitude of energy utilization is not well-defined as indicated by varying quantities being reported in the numerous documents discussing the U.S. energy budget.

Knowledge about the energy utilization characteristics for specific operations is essential to ascertain substitutability of currently available energy forms and to permit orderly transfer of new energy technology under development. Information about the interrelationships among the major energy consumption operations will also aid in modifications of current practices and/or development of alternative methodology (i.e., the condition of grain at harvest--moisture content, cleanness, and so on).

Implementation

A two-phase study should be conducted under the direction of a national research organization. Phase I would be devoted to assessing the energy characteristics (magnitude, forms, time and spatial distributions, and the interdependence of major operations) of the U.S. food system. Phase II would involve detailed analyses of the information obtained in Phase I and the development of alternative strategies for the system with changes of inputs. The analyses should include the assessment of the impact of national policies on the total system and the assessment of research priorities for utilizing new energy technologies and the energy potentials in agriculture products and by-products.

SUBSTITUTES FOR NITROGEN FERTILIZERS

Rationale

The single largest input in corn production and second in other crops is fertilizer; nitrogen requires the largest quantity of energy to produce (Table 1). A potential fertilizer source is the small percentage (about 10 percent) of livestock manure that is not now being used in crop production. Also a significant amount (as much as 50 percent) of nitrogen is lost from animal wastes that are stored and/or applied improperly.

Chemical fertilizer is applied to corn at an annual rate of 112 pounds of nitrogen, 31 pounds of phosphorus, and

Table 1 - Energy inputs in corn production (fully mechanized in the USA) (revised after Pimentel *et al.*, 1973).

Input	Quantity/ha	kcal/ha
Labor	22 hrs	
Machinery	1,037,400 kcal	1,037,400
Fuel	206 liters	2,060,000
Nitrogen	125 kg	1,897,500
Phosphorus	35 kg	111,650
Potassium	67 kg	147,400
Seeds	21 kg	147,840
Irrigation	187,720 kcal	187,720
Insecticides	1.12 kg	82,400
Herbicides	1.12 kg	82,400
Drying	296,400 kcal	296,400
Electricity	380,000 kcal	380,000
Transportation	172,900 kcal	172,900
Total		6,603,610
Corn yield	5,080 kg	17,881,600
Kcal return/kcal input	457	2.71

60 pounds of potassium (Table 1). A like amount of nitrogen is available from manure produced during one year by either one dairy cow, two young fattening beef cattle, nine hogs, or eighty-four chickens. In addition to the nutrients manure adds to the soil, it adds organic matter which increases the number of beneficial bacteria and fungi in the soil, makes plowing easier, improves the water-holding and percolation capacity of soil, reduces soil erosion, and improves the ratio of carbon to nitrogen in the soil.

The major costs of using manure for crop production are hauling and spreading. Hauling and spreading manure within a radius of 1/2 to 1 mile (1 mile = 1.6 kilometers) is estimated to require 1.1 gallons of gasoline per ton. If the average manure application is 10 tons per acre (produced by one cow for one year), an estimated 398,475 kcal (11 gallons of gasoline) per acre is necessary to apply the manure and hence to fertilize corn with manure. Producing chemical fertilizer (112 pounds of nitrogen, 31 pounds of phosphorus, 60 pounds of potassium) for one acre requires a total of 1,415,200 kcal. One gallon of gasoline is used for tractor application, therefore a total of 1,451,425 kcal for chemical fertilizer application is used. Hence, if manure were substituted for chemical fertilizer, the savings in energy would be a substantial 1.1 million kcal (about 28 gallons of fuel) per acre.

Current U.S. livestock manure production is estimated to be 1.7 billion tons per year, over 50 percent of which is produced in feedlots and confinement rearing situations. If 20 percent of the manure produced in feedlots and confinement rearing situations were available for use in crop production, about 170 million tons of animal waste would be available for crop production.

Nitrogen fertilizer inputs can be reduced by planting legumes in rotation with corn and other crops. For example, it is possible to plant legumes between corn rows in late August and to plow this green manure under in early spring. In the Northeast, seeding corn acreage to winter vetch in late August and plowing the vetch under in late April yielded about 133 pounds of nitrogen per acre. A cover crop also protects the soil from wind and water erosion during the winter and has the same advantages as manure in adding organic matter to the soil.

The energy cost of seeding a legume would require about 90,000 kcal per acre (fuel and seeds). For the commercial production of 133 pounds of nitrogen, 917,000 kcal are needed; thus the energy saved by planting a legume for green manure would be substantial or 827,000 kcal/acre (about 37 gallons of fuel).

Instead of inter-planting a legume with corn, another possibility would be to inter-plant corn in a perennial legume field. Preliminary experiments have been made with inter-planting corn in permanent stands of crown vetch. In the early spring the crown vetch is partially killed with an herbicide. The corn is then planted in the vetch field using "no-till" planting technology. Late in the season the vetch recovers after the corn has made its growth utilizing the nitrogen stored by the vetch during the previous fall and spring. The nitrogen yield is assumed to be similar to that of winter vetch.

Although the inter-planting technology can be applied to a relatively few crops, it does have great potential in reducing nitrogen inputs and reducing soil erosion with several important crops.

Large quantities of N, P, and K are available in sewage sludge and effluents, but several problems exist before these materials can be effectively used. These problems include:

(a) heavy metal contamination in some sewage;

(b) possible plant and animal disease organisms being transmitted to the treated crops; and

(c) removal of moisture in the material so that it can be transported more economically.

The new sewage treatment plants that have installed treatment procedures for the removal of N and P offer the potential of returning these two valuable fertilizer elements to agriculture.

Implementation

Steps for implementing research on substitutes for nitrogen fertilizers include:

(a) comparative studies of the value of animal wastes used directly for fertilizer versus the use for generation of methane gas for the manufacture of fertilizer;

(b) research on solving the problems associated with the use of sewage sludge as fertilizer; and

(c) research on methodology for using legumes as a means of supplying part of nitrogen requirements for other crops.

CONSERVATION OF ENERGY

Rationale

In addition to the energy used for manufactured input products, such as fertilizer, machinery and packaging materials, energy in the form of solar, electricity, petroleum fuels, natural, and LP gas comprise a large input into the U.S. food system. Various kinds of conversion processes are involved in the application of these energy forms. In the past, primary consideration was directed towards the effective applicability of the energy without optimizing its use.

Agriculture through the ages has been involved in the conversion of the sun's electromagnetic energy into chemical energy through the important biochemical process known as photosynthesis. The manipulation of plants and their environment to maximize the conversion process has been an important factor in the increased production of organic matter by U.S. agriculture. However, the relationship between organic matter production and solar energy availability indicates a very low rate of utilization or conversion. Increased efficiency of solar energy utilization would produce a greater return for other forms of energy inputs into plant production.

Machinery and fuel comprise a large energy input in U.S. agricultural production. A viable alternative for reducing the fuel consumption would be to use machinery precisely scaled for a given job and operate it at efficient speeds. The larger tractors and other machinery have been designed to do more work per unit time, but the increase in capacity and the better fuel efficiency at rated loads will be offset if utilized on loads requiring only part of the rated capacity or part-throttle conditions. In general, farmers purchase larger machinery than may be necessary as insurance against inclement weather and to enhance crop yield related to timeliness of operations. The major tillage operations will normally be the governing factor in the size of tractor purchased. Therefore, opportunities exist to reduce the power required for primary tillage as well as the size of machinery necessary for tillage operations.

Energy inputs in crop drying have increased drastically the past few years. Since 1945, a 30-fold increase in energy inputs for corn drying has occurred. The trade-off of reducing yields some, but advantages of harvesting a drier corn should be examined. Also the trade-off of harvesting corn on the cob vs. corn grain should be analyzed. With other grains, such as wheat, there is less of a problem with drying but there are also fewer alternatives.

Since most grains produced in the U.S. are fed to livestock, greater quantities of grains are going into "wet-storage." This provides some opportunities for storing grain without drying for about three months. The costs and benefits of this system need investigation.

Opportunities exist to improve the drying technology itself. Air temperature, air movement, and time are all factors in determining the most efficient means of reducing moisture in grain while also reducing the energy inputs.

Opportunities also exist for breeding grains that have a lower moisture level at harvest. These should be pursued.

Irrigation requires a high input of energy. Water is heavy (8.3 lbs/gal) and large quantities (up to 4 acre feet/acre) are needed for irrigation. The energy requirement to lift this quantity of water 300 feet and sprinkle irrigate is about 220 gallons of fuel. This is about 20 times the energy required for field operations for the crop. More efficient irrigation practices (e.g., trickle irrigation) can substantially reduce water requirements and energy inputs. Investigations on energy conserving irrigation practices should be increased.

Implementation

Steps for implementing research on conservation of energy include:

(a) greater emphasis on the biochemical process of converting the sun's electromagnetic energy into chemical energy;

(b) acceleration of studies on methods to reduce power requirements for primary tillage;

(c) development of more efficient grain drying equipment;

(d) improvement of storage of high moisture grain; and

(e) more efficient means of irrigation.

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CHAPTER 12

CROP AND LIVESTOCK PROTECTION

RECOMMENDATIONS

1: Pesticide Development, Formulation, and Application Technology. Increased effort is essential to develop new pesticides and the technology for their efficient and safe use in order to insure continuing availability of this technology for crop and livestock protection and for inclusion in Integrated Pest Management (IPM) systems.

2: Pest Management Systems. Interdisciplinary teams should be developed of crop protection, plant, and animal scientists to set up crop and livestock production systems which include integrated pest management.

3: Pest Resistant Crops and Livestock. Research efforts should be increased toward the development of pest resistant crops and livestock.

4: Biological Control. Research and development efforts should be increased to greatly enhance the role of biological control agents in reducing pest losses.

5: Innovative Methods. Research should be initiated for innovative methods to regulate behavior, development genetics, and reproduction of pests.

INTRODUCTION

The term "pest" as used here refers to all noxious organisms, including weeds, plant disease organisms, nematodes, rodents, insects, birds, and other pests. Similarly, the term, "pesticides" includes herbicides, fungicides, nematocides, rodenticides, insecticides, avacides, predator control agents, and others.

Pests take a heavy toll of man's food and fiber. Plant and animal protection problems have become increasingly difficult to solve as agricultural production has intensified. Some pest species serve as vectors of disease producing pathogens which can be destructive to plants and animals. Continuous cropping, monoculture, increased fertility, irrigation, narrow genetic base crop and livestock types, and centralized feedlots often increase the vulnerability of crops and livestock to pest attack.

Estimates of losses of potential crop production in North and Central America due to pests are 28.7 percent (FAO 1970). If we were to add losses that would occur without pesticides and other pest management inputs, total losses would be much greater. In fact, cotton and several horticultural crops cannot be produced commercially without such inputs, and livestock production would be impractical in many areas because of such pests as the screwworm and vector-borne diseases.

Losses to pests in the warm tropics are more severe than in the temperate zones. The tsetse fly prevents cattle production in vast areas of Africa. Arthropod and disease organisms must be controlled to permit useful and efficient livestock production in most warm climates. A significant portion of the "Green Revolution" potential for increased food production has been lost to the ravages of weeds, diseases, insects, rodents, and other pests.

In addition to field losses caused by pests, we must add postharvest losses. In the U.S. these have been reasonably well controlled by pest management practices in storage and rapid processing procedures. In developing countries postharvest losses are staggering. Microorganisms can quickly destroy most fruits, vegetables, meat, and milk and prevent proper distribution. Aflatoxins produced by microorganisms in such commodities as cottonseed and peanuts can be toxic to man and animals. Insects and rodents destroy grains. Stored grain losses due to pests in India are at least 40 percent.

The prevention of even a small part of the worldwide estimated annual loss of 33.8 percent of potential productivity due to pests offers a significant opportunity for increases in the supply of food (FAO 1970). Research, implementation, and educational inputs required to reduce pest losses in the U.S. should be made available quickly.

Attempts to prevent pest damage have resulted in the ever-increasing use of pesticides. Although these are generally used effectively in modern agriculture, there are exceptions. There are problems involving pesticide resistance and misuse, destruction of natural controls, environmental contamination, losses of nontarget species, and conflicting recommendations and actions by state, federal, and private sectors. Pesticide misuse and applicator intoxication are serious problems. Nevertheless, the safe use of pesticides remains essential to effective plant and animal protection and is an important component of integrated pest management systems.

The need for a systems management approach to crop and livestock production, including protection from pests, based on sound economic, ecological, technical, and societal considerations is critically needed. Simplistic approaches to crop and livestock protection have often been shortlived and, in many instances, have had unwanted side effects. The integrated pest management approach offers the greatest promise for effective, safe, and continuing solutions to pest problems.

Integrated pest management (IPM) has been defined as a

> pest management system that, in the context of the associated environment and the population dynamics and etiology of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains pest population levels below those causing economic injury (Glass 1975).

IPM tactics include resistant varieties, pesticides, cultural controls, biological controls, autocidal control, attractants and repellents, quarantine, and eradication. The proper employment of these is determined and supported by basic background biological information, economic thresholds, modeling, and agroecosystem analysis.

The recommendations for research included in this chapter have been selected because they are readily implementable and offer high probability for significantly increasing available food.

It should be noted that pests are of worldwide importance. Much of value to pest control in the U.S. has come from scientists and experience abroad. International cooperation in reducing pest movement is essential. Valuable pesticides used in American agriculture and public health fields were developed in laboratories in other countries. Food and fiber products in international trade require special consideration for pest control and/or levels of residues from pest fragments or chemicals. Worldwide control of vectors of disease is of great significance to the U.S.

Training of scientists responsible for present and future pest control policies and programs has assumed international importance. All parts of the world community need to be aware of the efforts in other areas that may related to pest management activities.

It is not the purpose of this discussion to detail the highlights of international pest management, but these remarks will indicate that failure to review it in more detail is by design and not an oversight.

More comprehensive analyses of deficiencies in crop protection and recommendations for improved integrated pest management procedures can be found in the NRC/NAS report, "Pest Control: An Assessment of Present and Alternative Technologies" (NAS, in press) and in other studies on integrated pest management.

PESTICIDE DEVELOPMENT, FORMULATION, AND APPLICATION TECHNOLOGY

Rationale

Pesticides provide rapid, effective, dependable, and economical means of controlling complexes of major agricultural pests. In many situations their use is known to be effective and without serious ecological effects. The major disadvantages associated with the use of pesticides are adverse effects on nontarget organisms and the development of resistant pest populations. Repeated use of selective herbicides causes a shift in species composition of the treated weed community and allows tolerant species to become dominant. This ecological shift requires rotation of herbicides. There is a great need for expanded research to develop ways to reduce or eliminate the inherent hazards of presently available pesticides and to discover new compounds free of these weaknesses.

The problems of pest resistance to pesticides continue to expand and intensify. They are more prevalent and acute among arthropod pests, but a few cases of resistance to herbicides and fungicides have been reported. In the past, resistance problems have been overcome by substituting different chemicals in the control program. However, because of the development by single pest species of multiple resistances to several pesticides and a reduction in efforts devoted to the development of new compounds in recent years, effective substitute chemicals are not available for control of some pests. Problems of pesticide resistance and shifts in the species composition of weed population must be met, at least for the present, by introducing effective new pesticides as substitutes for obsolete pesticides. Therefore, efforts to discover and develop new pesticides must be expanded. Also, costly regulatory constraints in registration and use of pesticides must be kept at the absolute minimum required to protect man and the environment. (See Chapter 5, Constraints on U.S. Agricultural Production and Research.) Otherwise, food production may be disastrously disrupted as has happened many times in history prior to the development of modern protection technology. Very substantial improvements in the efficiency, efficacy, and environmental safety of pesticide use can be accomplished through research on formulation and on application technology. Improved formulation and placement of herbicides can reduce environmental contamination and improve the contact with target organisms.

Implementation

Implementation of this recommendation is important for just maintaining the present level of pest protection in the U.S. and for improved protection on a number of crops and animals now suffering considerable pest-induced losses. The results will be highly complementary to developing countries because the patterns of pesticide use and availability in these countries often follow those in the U.S.

1. Accelerate research on more narrowly selective pesticides by identifying pests for which availability of narrow spectrum pesticides is most urgent. Strengthen national programs for developing use patterns of chemicals submitted by industry with procedures to safeguard proprietary rights and the public interest. Determine economic threshold densities of pests so that pesticides can be used only as needed rather than as prophylactics.
2. Encourage research on safe application procedures, formulations, and equipment required for more precise delivery and confinement of pesticides to target sites. This should include development of protection for application in the tropics.
3. Establish protocols for registration of new types of pesticides, such as microbial pathogens, hormones, pheromones, hormone-mimicking compounds, and chemosterilants for use in IPM programs.
4. Provide support and develop expeditious procedures for the rapid registration of pesticides for use on minor crops and for minor uses on major crops.
5. Initiate a worldwide study of the hazards of pesticide use and work toward the development of uniform and coordinated regulations for pesticide registration, use, and residue tolerances. Also, the uniform interpretation of toxicological data should be sought.
6. Make a cost/benefit analysis of regulations for pesticide and other pest management tactics, such as resistant crop varieties and quarantines.
7. Accelerate research on biologically active molecular structures, such as pyrethroids, naturally occurring growth inhibitors to develop new classes of pesticides.
8. Support research on the phenomenon of acquired resistance to pesticides and procedures for its prevention.

PEST MANAGEMENT SYSTEMS

Rationale

Agricultural scientists have been developing the various components of production of crops and livestock with at best a minimum of interaction between them. The integration of these separate components must usually be accomplished by farmers. Unfortunately, the components are sometimes incompatible or even counterproductive. Weed control and fertilizer practices may aggravate or reduce insect, disease, and rodent problems. Crop rotations or lack of them influence crop protection problems. Some pest management practices may adversely affect production or be incompatible with existing production systems. Thus, there is a great need to develop a total systems approach to management of crop and livestock agroecosystems which include compatible and effective integrated pest management components. Regional systems for detecting, assessing, and predicting pest infestations and pest losses should also receive strong emphasis.

Implementation

Teams composed of weed scientists, plant pathologists, nematologists, entomologists (and other protection specialists as needed), agronomists, plant breeders, animal scientists, food scientists, and economists should be established at land grant institutions and USDA units to develop total systems of production of crops and livestock. The crop protection scientists using a systems approach should develop suitable pest management tactics, such as host resistance, cultural practices, and pesticides, and work with production scientists to incorporate these into effective total farm management practices.

PEST RESISTANT CROPS AND LIVESTOCK

Rationale

Crop cultivars (varieties) resistant to pests constitute one of the most economically important and environmentally sound crop protection tools available. Good progress has been made through plant breeding in the control of plant pathogens, and some species of destructive insects. Varieties of potatoes resistant to the late blight pathogen, cereal crops resistant to species of rust fungi, and corn resistant to the southern leaf blight pathogen are familiar examples. Newer varieties of alfalfa have resistance to the alfalfa aphid; several introduced rice cultivars from the International Rice Research Institute (IRRI) in the Philippines are resistant to destructive species of leaf hoppers and stem borers. Weed scientists are following research evidence to determine the possibility of breeding crop varieties resistant to competing weed species. Breedings for pest resistance and tolerance in livestock have shown promise and should be encouraged.

The use of pest resistant cultivars may reduce pest populations, and it is compatible with virtually all other control tactics. It is also inexpensive. One major disadvantage associated with it is the development of pest races or biotypes able to overcome the resistance. Much effort must be expended in the development and use of pest resistant cultivars in integrated pest management.

Implementation

The steps described below are among those necessary for implementing this research.

(a) Genetic improvement programs for crops and livestock must be directed more specifically toward pest resistance objectives.

(b) A system for coordinating and for enhancing communication between plant resistance programs should be developed on a national and international scale. A national data bank on resistance and general improvement of germplasm resources should be established.

(c) Programs for the systematic exploration and characterization of useful sources of pest resistance should be strengthened and expanded.

(d) Permanent national and/or international systems for maintaining potentially useful germ plasm should be strengthened.

(e) Research on new techniques for hybridizing taxonomically diverse plants must be intensified to enhance the use of new sources of plant resistance.

BIOLOGICAL CONTROL

Rationale

Regulation of pest organisms by their natural enemies is of major importance in pest management. Increased funding, improved coordination of personnel and facilities at the exportation, importation-propagation and colonization-evaluation levels, and biological control approaches must be expanded to include pests other than insects and weeds (for example, plant pathogens).

Many indigenous pest species maintain low population levels, because they are controlled by natural enemies in the environment. Field experience since the 1940s with the application of synthetic organic insecticides has demonstrated that the natural enemies are often destroyed as well as the pest species. Frequently, the destruction of the natural enemies by synthetic organic insecticides results in the resurgence of destructive populations of the target pest species. The process may also trigger the emergence of a minor pest species into the status of a major pest through destruction of its effective natural control. The preservation and augmentation of naturally occurring biological control agents is essential. The effectiveness of such agents may be increased through the use of supplementary food sources and kairomones. The mass production and programmed release of natural enemies of pests deserves a special research and development effort.

Pathogens have been used effectively in control programs against weeds, insects, and rodents. Microbial agents are ideally suited to integrated pest management programs. They are host-specific and often highly virulent. They cause minimal ecological damage and are highly compatible with other forms of control.

Implementation

Steps in implementation of this research area include:

(a) The national effort to import, produce, distribute, and evaluate natural enemies of pests, including parasites, predators and pathogens of insects, other invertebrates, and weeds should be substantially increased. Also, research on programmed release of beneficial insects and on kairomones should be accelerated.

(b) Since biological control of pests is a complex undertaking in view of the ecological and biological knowledge required if it is to be successful, it must be undertaken and supported financially by the government, at all levels, in constrast to direct pest control measures that can be applied by individuals.

(c) In addition to an increased effort to import new pathogens, screening of available pathogens and their strains and serotypes against a wide spectrum of pests should be accelerated.

INNOVATIVE METHODS

Rationale

Opportunities for improved integrated pest management have been enhanced by recent identification of several powerful natural and synthetic attractants. The major uses of insect attractants include detection, monitoring for population densities, direct control by poison baits, mass-trapping or inhibition of premating behavior. The potential for using attractants offers opportunities for considerable reduction in the quantities of conventional insecticides employed. Attractants may be useful in concentrating parasites and predators in areas where pests exist. But these too will have their limitation. The feasibility of attracting or repelling nematodes should be explored.

Many organic herbicides act as selective plant regulators or synthetic hormones. They are used at concentrations which inhibit weed growth, but have little or no effect on crops. Plant growth regulators may have potential for stimulating germination of weed propagules (such as seeds, rhizomes, and bulbs) at a time when the physical environment is too harsh for them to survive. Conversely, chemical regulators might be used to prevent germination of weed propagules. More research is needed to elucidate the processes in dormancy of plant propagules. The potential use of plant hormones for modifying crops to reduce their susceptibilities to attacks by pest organisms should also be investigated.

Insect growth and development are also regulated by hormones, and insect growth regulators are already in commercial use. New and structurally simple molecular models of hormonal pesticides, such as anti-hormones and inhibitors of hormone biosynthesis and metabolism are needed. Additional hormones and neurohormones which regulate life processes unique to pests should be elucidated in order to develop models for interrupting such processes without hazard to higher animals and economic plants.

Most serious insect pests reproduce sexually. Geneticists have discovered or invented a number of mechanisms which may be useful in suppressing important pests. These mechanisms include compound chromosomes, cytoplasmic incompatibility, hybrid sterility, imbalanced sex determining factors, inherited partial sterility, chromosomal translocations, sex ratio distortion, dominant lethal mutations, conditional lethal mutations, and meiotic drive. Dominant lethal mutations are used operationally to suppress screwworms, tropical fruit flies, and the pink bollworm. The major difficulty in using genetic techniques to manage insect population lies in the behavioral changes that the pests undergo when they are colonized and mass reared. Experience with a few insects has shown that the field performance of mass reared insects is affected by their heredity, nutrition, and physical condition during rearing and release.

Implementation

The following steps are suggested for implementing the research area.

1. Establish and/or support existing research teams to investigate the identity and role of pheromones, kairomones, allomones, hormones, and other bio-regulatory substances.
2. Support research to determine the usefulness of such regulatory substances for crops and livestock protection.
3. Establish interdisciplinary teams of specialists to develop and demonstrate principles for assuring the behavioral adequacy of mass reared insects used to suppress pest populations by genetic methods or by parasitism.

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CHAPTER 13

MANPOWER EDUCATION AND TRAINING PROGRAMS

RECOMMENDATIONS

1: Education Needs. Studies should be instigated on identification and evaluation of U.S. professional and technical education needs to provide adequate human resources for the food system.

2: Fellowship and Research Training Programs in the Basic Sciences of Agriculture. Fellowship and research training programs should be established in the areas of agriculture, food science, and nutrition.

EDUCATION NEEDS

Rationale

Trained manpower is essential if the U.S. is to respond to national and international concerns to help solve the world food problem. The quantity of trained manpower required will increase, and the kind of training necessary will be different than in the past. A manpower training program should be a part of an expanded research investment in food production capacity. Research in agricultural production depends on manpower trained in agriculture, but with heavy emphasis on the biological and physical sciences. There has been a decrease in the training programs sponsored by NSF, the Atomic Energy Commission (AEC), and the National Institutes of Health (NIH) resulting in a decrease in training of basic scientists for research in agriculture. The Commission on Human Resources of the NRC has several ongoing studies of training programs for research. Training in biological and physical sciences as well as in agricultural production techniques is required for technicians in agricultural production. While there are several excellent examples of curricular and course changes in agriculture and renewable resources, a systematic review at the national level of the educational resource base and approaches to meet the needs is urgently required.

During the past few years, many changes have occurred in agricultural production, processing, and distribution systems in their rural and urban settings, and in their academic and theoretical underpinnings and interactions. A major correlate of these changes is the growth of colleges of agriculture and renewable resources, both in number of students and faculty and in the importance of the findings they generate in resolving many critical problems facing society. These trends are producing an opportunity in agriculture and renewable resource education to anticipate needs and introduce educational program changes which will prepare the kinds of professionals and technicians required for future challenges.

Undergraduate enrollment in agriculture in the state universities and land grant colleges more than doubled from 1963 to 1974, an increase of 134 percent. In 1974, enrollment for baccalaureate degree programs in agriculture increased 13.6 percent over 1973. Women in agriculture programs increased 23 percent. Enrollment in technical schools also showed an increase, but enrollment in graduate schools has not increased significantly. Guidelines for educational policy development for the broader academic community in undergraduate and graduate education in agriculture and renewable resources are critical needs.

Implementation

A study commission should be established to compile an inventory of manpower resources and project needs, and to assess the major issues and priorities for the development of education in agriculture and renewable resources. Competencies must be identified which professional and technical personnel must possess in order to further project national and international goals in food production.

Career directed education and training to be considered in this study should be conducted at three levels.

1. Post High School Technical Training

This includes vocational and technician training at community and junior colleges. It also includes subprofessional training provided by four-year colleges through the medium of short courses, conferences, seminars, and internships.

2. Academic Education at Degree Granting Institutions

This includes education at the baccalaureate level, the science and professional masters level, and the doctoral level. It includes education at the degree level whether or not at recognized schools and colleges of agriculture and renewable resources if such education purports to prepare students for professional careers in these fields.

3. Mid-career Education

This includes education for professionals in agriculture and renewable resources and for professionals whose education is in other fields but whose careers are or may be in agriculture and renewable resources.

FELLOWSHIP AND RESEARCH TRAINING PROGRAMS IN THE BASIC SCIENCES OF AGRICULTURE

Rationale

To meet the need for increased research in the basic science areas of agriculture, food science, and nutrition, highly trained research scientists are urgently required. Professionally and technologically trained manpower must increase in the areas of plant physiology, plant pathology, entomology, microbiology, plant and animal genetics, animal nutrition, veterinary medicine, agricultural engineering, food chemistry, nutrition, soil science, and agronomy. This can be most readily accomplished by implementation of a long-term program of support for graduate education in the sciences that are basic to agricultural production. Not only would such programs help the U.S. to better meet its food production and nutrition needs, but it would also help train people from developing countries to better cope with their problems.

Implementation

A board for international agricultural manpower development should be established to assist in administration of programs to develop training institutions and manpower to meet the present and projected needs for manpower in the U.S. and to assist in developing trained manpower to work abroad. The board should have an adequate budget and authority to award and monitor fellowships and training programs in the agricultural sciences. Fellowships should be made available to U.S. and foreign nationals on a competitive basis. Training grants should be made available to U.S. institutions for both U.S. and foreign nationals. The board should be authorized to foster collaborative relationships between agricultural manpower training institutions in the U.S. and agricultural institutions abroad where scientists are working or have the potential to work on significant programs designed to increase food production.

SECTION III:
PRODUCTION OF FOOD AND FEED CROPS

INTRODUCTION

The world's food supply begins with crops harvested from the land. However, the basic requirements and research needs for crops grown for human consumption are similar to those for feed, fiber, and fuel. Plants are a renewable resource and an increase in productivity will benefit food, feed, and biomass uses. But plants require, and may compete for, the nonrenewable resources of land, water, energy, fertilizer, and chemicals. Many plants (e.g., feed grains and grain legumes) can be routed as either food for man or feed for livestock. Others, such as the grasses and forages, are useful only to livestock. Biomass production of plants is already widely used for fiber and may again be more extensively used for fuels.

The significance of food and feed crops is that they provide, directly or indirectly, about 90 percent of the world's food supply. Chief among the major food crops are rice, wheat, maize, sorghum, millet, barley, rye, oats, soybeans, field beans, chick peas, pigeon peas, peanuts, cassava, sweet potatoes, potatoes, sugar beets, sugarcane, coconuts, and bananas. A variety of fruits and vegetables, processed and fresh, adds personal enrichment and pleasure in eating and provides essential dietary nutrients. Hay and pastures (grazing crops) provide most of the feed units for cattle and sheep. Current rates of population growth and changes in dietary habits will double the need for these crops during the final quarter of the twentieth century. Our forests and tree plantations provide fiber, as do some feed and food crops. New fast-growing, high-yielding crops will have to be developed for biomass production of fuel, as well as food and feed.

Crop production is a central issue. Global production of grain must be increased at the rate of 25 million metric tons per year just to keep pace with population increases and rising demands. Fuel production will become critical as we exhaust our oil and gas reserves. Chemists, microbiologists, and engineers will have to convert massive amounts of organic plant material to basic chemicals for industry and fuel. Nature did this slowly in the past from plants. Now man will have to do it quickly as he increasingly uses plants for food, feed, fiber, and fuel.

There are major uncertainties involving future agricultural needs, including adequacy of land, water, energy, fertilizer, and pesticide resources. There are environmental, social, political, legal, and economic constraints, and numerous disincentives in agricultural food production. Weather and changing climatic patterns continue to play a predominant but unpredictable role in dictating the selection of crops tolerant to change.

A national program for greater food production and improved nutrition must focus on the major food and feed crops. Research investments are needed to maximize or optimize the production of food crops per unit of time, with the least expenditure or commitment of land, water, fuel, and fertilizer. The two most important processes that use solar energy are photosynthesis and biological nitrogen fixation; research on these processes can be expected to lead to greater production of carbohydrates, proteins, fiber, and energy.

CHAPTER 14

PHOTOSYNTHETIC PRODUCTIVITY

RECOMMENDATIONS

1: Efficiency of the Photosynthetic Process. The impressive yield increases of the past 25 years have come from a combination of new varieties, high rates of fertilization, high plant populations, disease resistance, and control of insects and weeds. Further significant yield increases will require greater photosynthetic efficiency. Therefore, need is great to expand research on the factors which control the photosynthetic process, especially in four areas: (1) control by source-sink relationships; (2) control of photorespiration; (3) control of plant senescence; and (4) carbon dioxide enrichment and other improvements of field techniques for crop production.

2: Use of the Seasonal Potential. In much of the U.S. there is a waste of potential photosynthetic production because the photosynthetic system in the crops grown is poorly adapted to either warm or cool weather or length of growing seasons; whereas other species may have their most rapid growth during those times. The potential needs to be evaluated for developing crop varieties which can produce rapidly in both cool and warm weather and in variable growing seasons. Planting designs and multiple cropping should be developed to capture maximum solar energy.

INTRODUCTION

It is estimated that world food production must double by the year 2000. Adoption of currently available agricultural technology could alter yields in the agriculturally developing nations by a significant amount; but for yields to double in the U.S. or other developed countries, which produce much of the total and all of exportable food, will require a marked increase in photosynthetic productivity over the levels achieved in current agricultural practice.

We often hear faith expressed in the ingenuity of American agriculture. Many knowledgeable people suggest, on the basis of past performance, that the percentage gains in crop yields over the past 25 years will be repeated in the 25 years ahead. Such projections need careful analysis.

One of the better examples of success in agriculture is the yield increase that has occurred in corn production in the U.S. In 1950, average yields were 57 bushels per acre (bu/A). The estimated yield for 1975 is 93 bu/A. That impressive increase has been due to new disease resistant varieties which are responsive to narrow row spacing and high fertility as now practiced. Extremely effective chemicals for controlling weeds are now almost universally in use. This combination of variety, spacing, high fertility, and freedom from weeds has resulted in the current high yields. It is that technology which could contribute to yield increases in the agriculturally developing countries.

Could corn yields be increased in the U.S. by the year 2000? With the high price of grain and the removal of acreage controls, all crop land readily and presently available is being farmed. Increases in crop acreage will come slowly and at considerable cost. Thus, about the only possibility for exploitation of further yield increases on our most highly productive land is to develop higher yielding varieties.

Where can the varietal input to yield come from in a crop such as corn? Considerable progress has been made in recent years by developing varieties which put more of the photosynthetic yield into grain. Today, about one half of the total plant weight at corn harvest is grain, the remainder being stalks, leaves, and roots. The roots, stalks, and leaves are absolutely essential to the plant. Possibly this proportion can be somewhat further reduced, but in order for grain yield of corn to double, an increase in the photosynthetic yield of the crop also must be attained. Thus, the future of the world's food supply may lie squarely at the door of photosynthesis and its partitioning into the harvested part.

What has been the history of photosynthetic yields while these remarkable successes in grain yield have been obtained in corn? They have increased, but the startling fact is that the biochemical capacity of corn for photosynthesis has not changed at all. The photosynthetic yield increase has been achieved by more dense plantings, earlier plantings, later harvests, steadily increasing rates of fertilizer application, and the relative freedom of the crop from pests and disease. While we are faced with need in the future to drastically alter the capacity of crop varieties for photosynthesis, we have made no progress in increasing the efficiency of the process in the past 25 years, and we are nearing the limit of exploitation through technology. To make further progress we must improve the photosynthetic process itself, yet we have currently only a token research effort on photosynthetic productivity.

The photosynthetic yield of an acre is derived from the photosynthetic rate per unit area and time of individual leaves multiplied by the area of those leaves contained on an acre (the leaf area index or LAI) and the length of time the system functions. The entire system is driven by solar energy. Although the preceding statements seem obvious, each of these points becomes important when we consider potential research on photosynthesis.

EFFICIENCY OF THE PHOTOSYNTHETIC PROCESS

Rationale

As indicated above, the biochemical efficiency of the photosynthetic process in major crops has not changed in the last 25 years. Yet great differences in efficiency exist between crops. In the warmth of midsummer, corn and sorghum and sugarcane are highly efficient, greatly surpassing such summer crops as soybeans or potatoes. In cool spring weather, however, photosynthesis in wheat, barley, or rye greatly surpasses that in the warm season crops.

In the past decade it has been discovered that corn, sugarcane, and some other crops have photosynthetic systems that consist of a sequence of biochemical events strikingly different from that which occurs in wheat or barley. The enzymes involved have high optimum temperatures and function very effectively in high temperatures and intense sunlight. The relationship with season is not clearcut, however; soybeans do best in warm weather, although they possess the same biochemical system for photosynthesis as wheat or barley.

Since striking differences exist among crop species in efficiency or photosynthesis and in the adaptability of the photosynthetic enzyme systems to seasons, the potential to alter the photosynthetic process in ways useful to man seems great indeed. Yet progress has been nil in breeding crop varieties which have superior photosynthetic yield capacity. The photosynthetic rate in crop species has proven to be highly variable in time and subject to enormous environmental influence. Progress in vital areas is unlikely until the factors that control photosynthesis are understood.

Implementation

Research on factors that control photosynthesis is sorely needed in four different areas.

1. Control by source-sink relationships

New growth or the development of fruit or grain enhances leaf photosynthetic rates. On the other hand, ample photosynthesis is necessary to produce the potential for a large fruit or grain yield. The signals that pass between leaves and other organs which tell the leaf to increase or decrease its photosynthesis are not understood. The factors that control the fate of photosynthate--whether it goes to storage in grain or fruit, becomes part of the plant structure as new leaves or roots, or is respired, wastefully or to provide plant energy--are largely unknown. It is critical that research efforts be greatly expanded in this area.

2. Control of photorespiration

In plants such as wheat or soybeans the enzyme responsible for fixing carbon dioxide and forming carbohydrates can also react with oxygen. When this happens, carbohydrates are destroyed--not produced--and as far as is known, wastefully so. When this destruction of carbohydrates occurs, the process is called photorespiration. Corn, sugarcane, and several other highly productive crop species have evolved a photosynthetic system which protects its carboxylating enzyme from photorespiration. It is estimated that the photosynthetic yield of wheat, rice, soybeans, and many other crops could be increased by up to 100 percent if a genetic or chemical inhibition of photorespiration could be attained. Research on this topic needs much more emphasis than it is now getting.

3. Control of senescence

The photosynthetic capacity of all the grain crops (including soybeans and other legumes) decreases precipitously during the grain-filling period, exactly at the time when the need for photosynthesis is greatest. It appears that, in selecting crops for uniform ripening so that they are amenable to machine harvesting, varieties of many crops have been developed which are now limited in their yield because their photosynthetic factories close down too soon. We must understand the control mechanisms within plants that tell it to mature and die. The potential seems great to markedly alter yields simply by keeping the photosynthetic factor going for a longer period of time. This area also needs research effort.

4. Carbon Dioxide Enrichment

The carbon dioxide concentration available to plant foliage is the most important variable determining the rate of photosynthesis. For example, a sixfold increase in N_2 fixation for soybeans has been achieved by a threefold increase in atmospheric carbon dioxide (Evans 1975). Experimental and commercial results confirm that major growth increases, often exceeding 100 percent, can occur with increases in the carbon dioxide concentrations in the atmosphere. Heretofore, textbooks on crop fertilization, with few exceptions, have ignored carbon dioxide as a plant nutrient from which growth responses may be derived. This blind spot in management for food producing systems needs serious reappraisal. Although the knowledge of carbon dioxide benefit by crops grown in greenhouses has been known for half a century, and was put to use to a limited extent during World War II in Germany, it has not been pursued as a researchable means of maximizing the productivity of field food crops. Massive supplies of carbon dioxide are dumped into the atmosphere and could potentially be used for enhancing crop production. There are also large geological resources of carbon dioxide adjacent to major food producing areas in Texas and the Mississippi Delta.

USE OF THE SEASONAL POTENTIAL

Rationale

Since photosynthetic yield is a product of rate and time, one obvious way to increase biomass production is to increase the proportion of the time that a crop occupies the soil. The practice of multiple cropping which is practiced intensively in some subtropical areas has the potential for much wider application in the world. If varieties of summer crops could be developed which had a cool season capability for photosynthesis, plantings could be earlier and seasons extended on many millions of acres.

Research in this area is almost nonexistent in temperate climates. Yet crops such as winter wheat or rye are capable of producing tons of biomass per acre each spring before corn is even planted in the Corn Belt. Obviously, such crops do not mature grain before corn is planted, but the point to be made is that large amounts of solar energy go unharnessed because the summer crops lack a cool season photosynthetic capacity. The potential needs to be evaluated for using the seasons more fully.

CHAPTER 15

BIOLOGICAL NITROGEN FIXATION

RECOMMENDATIONS

1: Research Teams in Nitrogen Fixation. Research teams should be established for the purpose of conducting coordinated efforts toward obtaining in-depth knowledge of the nitrogen fixation process and its application in production of food, feed, and fiber; control of soil erosion; and maintenance of ecological balance.

2: Rhizobial Technical Center. A rhizobial center should be established to provide leadership and expertise in the technology essential to effective legume inoculation.

INTRODUCTION

The major portion of all nitrogen required for the production of food, fiber, and other plant products is derived from the atmospheric reservoir through biological nitrogen fixation and industrial chemical fixation. The biological fixation process is indirectly dependent upon solar energy that is stored by plants in products of photosynthesis. Organisms capable of using atmospheric nitrogen ordinarily are not dependent upon another source, but those lacking this capability require nitrogen from fertilizer or from soil reserves.

The chemical synthesis of compounds of nitrogen and their distribution for fertilizer require enormous quantities of hydrogen from natural gas plus additional energy expenditure to maintain the temperature and pressure for synthesis and to transport the products to their destination. In 1972, 465 billion cubic feet of natural gas or 2 percent of all the natural gas used in that year was consumed for the production of anhydrous ammonia.

New methods have revealed that biological nitrogen fixation is more widespread than originally imagined. In the U.S. alone, the quantity of nitrogen fixed by agricultural and nonagricultural species has been estimated to exceed 23 million U.S. tons annually (Evans 1975). In addition to agricultural legumes, biological nitrogen fixation also is of major importance in forests, woodlands, arid regions, and in fresh water and marine habitats where the quantity fixed per year may approach that fixed annually by agricultural legumes. Since nitrogen is the major plant nutrient limiting the production of food, fiber, and other products for an expanding population, it is essential to exert maximum effort to increase the supply of a usable form of this element by both biological and chemical means. An increased supply of biologically fixed nitrogen may be accomplished without excessive use of our energy resources. Furthermore, biological nitrogen fixation takes place in the fields, forests, and other environments where it is used. Transportation is not a major factor, and most importantly the capital investment for the construction of factories for nitrogen fixation is unnecessary. Expansion of biological nitrogen fixation capabilities in the agriculturally developing countries is now being and should continue to be vigorously encouraged.

RESEARCH TEAMS IN NITROGEN FIXATION

Rationale

During the past 30 years, agriculturists have used relatively inexpensive fertilizer nitrogen for their crops, and research on such practical problems as legume inoculation, rhizobium strain effectiveness, and use of legume cover and green manure crops has declined. Responsibility for the manufacture, testing, and maintenance of the quality of rhizobium inoculants has been delegated to commercial manufacturers. Many of our well known experts in rhizobium bacteriology have retired, and the supply of well-trained young scientists in the field is at a low level. During the past two years the price of fertilizer nitrogen has more than quadrupled, and the current cost to farmers of nitrogen as anhydrous ammonia is $250 per ton. Fossil fuels represent 50 percent of the current cost of ammonia manufacture, and fossil fuels are becoming scarce and more expensive.

While there has been a declining interest in the more applied areas of biological nitrogen fixation, research on the detailed biochemical properties of the nitrogen-fixing complex and related enzymes has proceeded at a rapid rate, and new methodology for the investigation of broad aspects of the process is now available. The acetylene reduction technique for measuring nitrogenase activity and relatively new methods for transferring nitrogen-fixing genes from one bacterium to another, for example, provide an opportunity for some major advances in the field. These opportunities include: (a) the improvement of nitrogen fixation by leguminous crop plants, (b) extension of the nitrogen-fixing capability to additional plants, (c) discovery of new and use of existing nitrogen-fixing organisms in nature, and (d) discovery of new chemical mechanisms of nitrogen fixation based on the chemical process that occurs in nitrogen-fixing microorganisms or on the development of the chemistry of nitrogen fixation under mild conditions (of temperature and pressure) by homogenous catalysts. In order to take advantage of these opportunities, training programs in some areas need to be encouraged and interdisciplinary research teams need to be organized. A rhizobium technical center is needed as a service to research workers in this and other countries, to manufacturers of inoculants, and to farmers.

Implementation

Federal and state agencies already have a substantial investment in facilities and personnel now conducting research in several aspects of nitrogen fixation. Therefore, research teams of 10 to 12 scientists should be organized by supplementation, where possible, of staff and facilities that are already in operation in laboratories and field stations with strengths in areas such as microbial genetics. In some areas new teams will need to be organized while in others, additional staff appointments and/or additional facilities could create dynamic research units. Success will require coordination of efforts by several agencies such as CSRS, ARS, USAID, and NSF.

1. Teams Assigned to Forage and Grain Legumes

A team consisting of agronomists, soil scientists, plant nutritionists, bacteriologists, bacterial geneticists, plant geneticists, plant physiologists, biochemists, and extension specialists (the number to be determined by the need) should be located in each particular region of the country where grain and forage legumes are of major importance. The primary goal of each group should be to develop new and/or use existing bacterial strains and host cultivars and the most efficient agronomic practices for the production of maximum quantity of high quality food and feed.

Since many of our legume cultivars have been developed in areas where high populations of indigenous rhizobia of unknown effectiveness were present, plant geneticists, bacteriologists, and agronomists must reevaluate efficiency of nitrogen fixation by leguminous crops in order to determine whether or not the most effective combinations of rhizobium strains and leguminous hosts are being used. Also they must determine the factors that influence the survival and competitiveness of rhizobium strains in different environments and whether present inoculation techniques are adequate to insure that applied inoculum is capable of competing with existing populations of indigenous rhizobia. Plant physiologists, plant nutritionists, and biochemists, for example, should contribute to the team effort to enhance nitrogen-fixing capability by identification of those physiological, nutritional, and environmental factors that limit the process and by a search for methods for the alleviation of limitations. These endeavors will include the identification of the products of photosynthesis that are transferred to nodules as sources of energy for the support of nitrogen fixation and the definition of environmental and physiological conditions that limit nodule photosynthate supply under both laboratory and field conditions. Also the metabolic systems that participate in the transfer of products of nitrogen fixation out of nodules and the control mechanisms that influence the nitrogen-fixing process and closely related processes need to be characterized. The biochemical basis for the specificity of the infection of legumes by rhizobium species and strains needs to be understood. The information obtained may then be used in attaining the primary goal listed under Recommendation 1.

2. Teams for Grain and Forage Grasses

A team located in the subtropical region of the U.S. should be organized to determine the magnitude and potential importance of biological nitrogen fixation on the roots of grasses and other species of agricultural importance. This team should include plant geneticists, microbiologists, agronomists, and plant physiologists who should direct their efforts toward such goals as determination of the magnitude of nitrogen fixation on the roots of corn, sugar cane, and subtropical forage grasses. Microorganisms responsible for fixation should be identified, compatibility of grass cultivars and bacterial strains should be tested, and the optimum environmental and other conditions for nitrogen fixation on or within grass roots should be defined. These investigations are particularly pertinent since Dobereiner in Brazil (Evans 1975) recently has described associations of bacteria on roots of *Paspalum notatum* and *Digitaria decumbens* that are claimed to fix nitrogen at rates up to 100 kg of N per year. Measurements of field increases, however, have not been reported. Nitrogen fixation is known to occur on roots of grasses in temperate zones, but rates reported are relatively low.

3. Teams for Forests, Woodlands, Aquatic, and other Habitats

Research teams consisting of phycologists, microbiologists, physiologists, mycologists, ecologists, foresters, and statisticians should be organized for the purpose of evaluating in quantative terms the contribution of fixed nitrogen to our non-arable lands, forests, aquatic, and other environments by the variety of non-leguminous nitrogen-fixing systems that are now known to exist. This is necessary in order to evaluate their contribution to food, feed, and fiber production and their role in controlling soil erosion and maintaining of ecological balance. Some of these systems include: free-living blue-green algae; nitrogen-fixing bacteria; associations of nitrogen-fixing bacteria with roots of herbaceous species and with fungi in rotting wood; associations of blue-green algae with fungi, liverworts, mosses, and ferns; and symbiotic associations between unidentified microorganisms and woody species, such as *Alnus, Ceanothus, Purshia, Myrica,* and *Dryas.* If the basic biological characteristics of these nitrogen-fixing systems were understood, intelligent management and therefore maximum use of them could be made. A major objective, for example, would be to obtain pure cultures in laboratory media of the nitrogen-fixing endophytes of *Alnus, Ceanothus, Myrica, Purshia, Dryas,* and *Comptonia.* None of the endophytes in nodules of nitrogen-fixing woody species can be cultured at present, and as a consequence, methods for preparation of inocula that could be used to increase the extent of nodulation of these species have not been perfected. Also a search should be made for new naturally occurring nitrogen-fixing systems that are closely associated with plants.

4. Basic Genetics Teams

Teams should be organized for the purpose of using genetic and cell-fusion techniques in extension of the range, extent, and usefulness of biological nitrogen-fixing capability. For example, genetic techniques should be employed to attempt to transfer nitrogen-fixing genes into additional bacteria of economic importance and to enhance biological nitrogen-fixing capability of organisms already known to fix nitrogen, by genetically altering control mechanisms that influence nitrogenase synthesis. Efforts should be directed toward the development of mutant strains of rhizobium with advantageous alterations in their specificity toward hosts. As a long-term objective this team also should attempt to incorporate nitrogen-fixing capability into tissues of crop plants, such as corn, wheat, or sorghum, and to develop strains of nitrogen-fixing bacteria with a capability of invading or associating themselves with roots of grass species and establishing effective nitrogen-fixing associations.

5. Basic Biochemical and Chemical Research Teams

Research teams should be organized for the purpose of continued improvement of understanding of the chemistry and biochemistry of biological nitrogen fixation by elucidation of detailed chemical changes that take place during the reduction of nitrogen gas to ammonia by nitrogenase and by chemical model systems. This objective requires collaboration of physical chemists, inorganic chemists with expertise in metal complexes, protein chemists, and enzymologists who are familiar with the detailed properties of nitrogenase. In addition to providing a basic understanding of the biological nitrogen-fixing process, this research offers the possiblity for discovery of new chemical mechanisms of reducing nitrogen.

6. Nitrogen Fixation in Conjunction with the Microbiological Degradation of Waste Carbohydrates

A team consisting of microbiologists, microbial geneticists, physiologists, biochemists, and engineers should be organized for the purpose of increasing the availability of fixed nitrogen by utilization of the energy in waste materials, such as corn stalks, grass straws, and wood products as substrates for the support of microorganisms, including those capable of nitrogen fixation. Precedent for this research already has been provided by the discovery of large populations of nitrogen-fixing bacteria in the decaying heartwood of forest trees (Evans 1975). The economic feasibility of these principles in the use of cellulose and other components of waste materials needs to be evaluated. The magnitude of operations could range from those designed to use large-scale industrial and farm by-products to small compost units for home gardens.

RHIZOBIAL TECHNICAL CENTER

Functions of a rhizobial technical center should include: (a) acquisition and storage of a world collection of rhizobia to insure the availability of a valuable collection of diverse types of rhizobia to researchers in this country and other countries; (b) collection of new rhizobial isolates to enable improved strain selection; (c) evaluation of rhizobial accessions; (d) training of technologists to work on the many aspects of selection, production, testing, and distribution of rhizobia; and (e) aid to the responsible government agency in the control of the quality of commercial inoculants. This center would provide technical service to the research teams listed above (1 through 5) and also services concerned with the use of microorganisms for the inoculation of non-leguminous species if justification for this is provided by current and future research.

CHAPTER 16

CROP IMPROVEMENT

RECOMMENDATIONS

1: Plant Genetic Resource Management. An immediate program of systematic assembly, maintenance, evaluation, and use of plant genetic resources should be undertaken, including the development of improved techniques for exploiting plant genetic resources.

2: In Vitro Techniques. Studies should be supported on technology for genetic transfer in plants through *in vitro* techniques for crop improvement, with emphasis at centers where interdisciplinary teams already exist or can be formed.

3: Chemical Control. Efficient and practical methods for the chemical control of plant growth should be developed.

4: Micronutrient Elements. The possibility that food and feed crops require additional micronutrient elements should be investigated.

5: Protein Quality and Quantity and Nutritional Availability. Research should be intensified on the genetic improvement of protein quality and quantity in cereals and cereal legumes, and on the biological verification of the nutritional value of the modified protein.

6: Protein from Oilseeds. Research should be intensified on increasing the protein in oilseeds by improving gossypol-free varieties of cotton, on yields and changes in types of fatty acids in sunflower, and on new varieties of soybeans to increase their range and yield.

PLANT GENETIC RESOURCE MANAGEMENT

Rationale

The important food crops grown in the U.S. originated outside the U.S. and have been imported. The genetic lines of these crops are becoming increasingly uniform.

An important aspect in maintaining the genetic variability upon which man depends for future breeding programs is the preservation of a maximal range of genetic stocks. It will be important to provide adequate steps for preserving genetic materials.

The Agricultural Research Policy Advisory Committee (ARPAC) of the Agricultural Research Service (ARS/USDA) has recommended a genetic resources board to devise a national plan and program of genetic resource management. It is important that such a plan be implemented in order that germ plasm from centers of diversity will not be lost.

Crop productivity at the genetic level is limited by the genetically-controlled growth responses to environmental resources and stresses. Sufficient information is available to support the expectation of high sustained yields <u>if</u> the physiologic genetic processes regulating the <u>vigor</u> of plant growth could be understood and brought under agronomic control.

Most frequently, specific useful characters or combinations of characters occur in only a small fraction of a population of basic stocks or endemic strains of a species. Ways need to be found to simplify and expedite the identification of characteristics useful for meeting given objectives.

Environmental stresses on crop plants are a fact of life that must be faced as we seek knowledge and develop technology for meeting our basic needs for sustenance. The genetic approach is ecologically nonpolluting and energy conserving. Sustained, debilitating drought may occur again over major parts of our most important crop production areas. Air pollution is limiting crop production in some areas (Benedict et al. 1973). Widespread culture of genetically similar varieties may result in greater losses from environmental stresses than would otherwise be the case, particularly if the varieties have not been selected for stress tolerance. Rather than add chemicals to change the soil to fit the plant, it now appears wiser in some uses to change the plant to fit the soil. Selecting or breeding plants more tolerant to salinity is a case in point. Better understanding must be sought of (a) differences among strains and varieties in their ability to withstand stresses, and (b) the alternatives that are available for continuing to produce adequate supplies of food, feed, and fiber in situations of extreme environmental stress.

We need to strengthen current efforts to transfer genetic material from one species (or genus) to another by means of conventional crossing procedures. Dramatic examples of successful transfer can be cited: leaf rust resistance from wild *Aegilops* species into wheat and golden nematode resistance from wild *Solanum* species into potatoes. Related wild species of our crop plants represent a source of genetic material that has hardly been tapped.

IN VITRO TECHNIQUES

Rationale

Great strides have been made in what is being called the "new botany," that is, the production of new types of plants without recourse to sexual reproduction by using the *in vitro* techniques of cell and tissue culture. The approaches afforded by these recent advances have great potential for plant breeders.

New techniques are now feasible because of the progress made in plant cell culture during the past decade (Chellef and Carlson 1974). These include: (1) meristem culture for the propagation of plants difficult to multiply and to free infected plants of viral, bacterial, and/or fungal contaminants; (2) embryo culture for growth of plants which naturally abort before or soon after germination (because of incompatibility with maternal tissue or because of the production of toxic materials by the maternal tissue); and (3) the long time storage under liquid nitrogen of germplasm of vegetatively propagated plants, such as fruit trees, shrubs, and potatoes. In addition, there are techniques which can be used at the cellular level for the manipulation of plant systems including: (1) exploitation of spontaneous variation in cell and tissue culture, polyploidy, aneuploidy, and chromosomal mosaics; (2) induced mutations; (3) induced polyploidy (particularly doubling of chromosomes through the use of the alkaloid colchicine); (4) haploids (individuals with only one set of chromosomes in the vegetative state, a condition in higher plants usually reserved for sex cells) plants from pollen or from anthers; (5) fusion of protoplasts produced from vegetative cells; (6) transformation (to change the heritage of one strain by introducing the chemical carrier of heredity from another strain); and (7) efficient selection and screening procedures to recover desired cell or plant types from large populations.

New plants have already been obtained using these approaches. Success has been achieved in obtaining mutants resistant to several diseases and to environmental stresses. Fusion of protoplasts from vegetative cells from different species of *Nicotiana* to produce a hybrid plant has been demonstrated. The hybrids are similar to those produced by sexual methods, demonstrating that the approach is theoretically sound. Transformation in higher plants is in infancy, but some investigators believe this approach to be the most effective because it should allow more directed change with better control and definition of the desired modification.

The most effective use of these new techniques will be realized when selection can be coupled with directed change. Support is needed for studies of selection methods at the cellular level. The agricultural implications appear to be significant: possibilities include not only new plants not possible through the sexual process, but also higher yielding lines, increased disease resistance, and even production of desirable products in more than one part of the plant.

CHEMICAL CONTROL

Rationale

Compounds that control crop maturity could have an important economic impact in the foreseeable future. These chemicals can increase yields by effecting metabolism, preventing losses due to failure to achieve maturity or to the delay of the timing of maturity, limiting fruit set, and delaying fruit drop.

An excellent example of the positive results achieved in the recent past is the use of chemical ripening compounds in sugarcane resulting in a 10 to 15 percent increase in yield of the economic product, in this case sucrose (Nickell 1974). There is every reason to believe that changes in cultural practices to adjust to this new approach will give additional yield increases. Similarly, the use of a naturally occurring growth stimulant nearly doubles both yield and sugar content of seedless grapes (Weaver 1972).

The success in sugarcane and grapes strongly suggests the desirability of studying other systems in increasing metabolic products in the vegetative stage of crop production, and it is not unrealistic to propose inaugurating similar approaches to sexually produced crops. Recent studies have shown that the inhibition (or delay) of senescence in small grains substantially increases yield (Weaver 1972). It has also been found that legume nodules cease fixing nitrogen and start to disintegrate when their carbohydrate supply decreases from the shoot.

In addition to these direct effects on yield increases, there are other indirect ways to improve yields or to prevent losses. One is to delay or speed up the flowering time in crops, such as cotton, so that there are no developing young fruit to serve as hosts for the insect pests. Another is to control the germination, growth, and development of plant vegetation to synchronize with the rainfall distribution pattern for semi-arid areas.

A combination of chemical control over plant growth with development of new plants through *in vitro* techniques may enhance the potential of both approaches to crop improvement. Development of specific chemicals to adjust the physiological mechanisms of new plants should be moved ahead concurrently and with close liaison among the researchers involved in both activities.

MICRONUTRIENT ELEMENTS

Rationale

The first step in meeting the mineral nutrient requirements of man and animals is the absorption of the required minerals by plants growing on soil. In many instances, the concentrations and ratios of the minerals in the plant are not those most desirable in human and animal diets. The problem is most critical with some of the so-called "trace elements"--iron, zinc, selenium, copper, iodine, cobalt, and others. Recognition and correction of some mineral deficiencies in animals that stem from deficiency in soils and are reflected in plant composition have increased food production and permitted animal agriculture to expand into new areas (Allaway 1975). But mineral deficiencies in humans and animals still persist as evidenced by widespread iron deficiency or by the recently established zinc deficiency in people. Correction of these deficiencies by direct supplementation of people and animals has met with mixed success in the developed countries and will face additional difficulties in developing countries where food technology is not advanced. In addition, the people of many developing countries must depend primarily on direct consumption of plants to meet calorie requirements, without the animal acting as an intermediate collector of essential minerals and a barrier to the transfer of toxic minerals and antimetabolites. Several elements--silicon, chromium, vanadium, nickel, and others--have recently been added to the list of those essential or probably essential, for man and animals, but relatively little is known about how these elements move through food chains. Other elements will undoubtably be added to the list of those essential for plants or animals.

It is now appropriate to try to improve plants as sources of dietary trace elements for people and animals, to identify and correct malfunctions of the trace element food chain that are unique to certain geographic regions, and to develop plants that will be better sources of minerals than any of those grown up to now. The research should include efforts to control the concentration of minerals in food and feed crops plus efforts to improve the digestibility and nutritional value of minerals in plants.

Implementation

Nutritional researchers should attempt to control movement of essential and toxic minerals from soils to plants to animals. The approach should include studies of the chemistry of these elements in soils directed toward development of soil tests that can be used to predict the concentration of specific elements in the edible parts of plants, and to predict how this concentration will change under different fertilizer additions or soil management practices. The processes of uptake and translocation of these elements in plants should be investigated along with the factors affecting the chemical combinations of these elements in the plant. Plant breeders should be assigned to develop food and feed crops that are adapted to specific trace element environments or may be efficient accumulators of different minerals. The work of these scientists should be supplemented by nutritionists who investigate the digestibility and nutritional function of elements contained in different plants and who establish plant composition goals based on human and animal requirements for different elements, or on critical concentrations to prevent toxicity from others.

PROTEIN QUALITY AND QUANTITY AND NUTRITIONAL AVAILABILITY

Rationale

In a world in which animal protein will become increasingly costly, plant proteins will have to provide a greater share of the protein intake of people everywhere. This requires that plant proteins be of adequate nutritional value when ingested in diets of adequate caloric value. In classic cases, particular amino acids have been shown to be nutritionally limiting, and genetic mutants have been found which alter their levels in seeds. The different cereals of economic importance all have one characteristic in common--they are low in the essential amino acid, lysine. Because of the lack of adequate lysine, cereal proteins are inferior nutritionally to the proteins found in milk, meat, eggs, and grain legumes.

With the discovery 10 years ago that the maize mutant opaque-2 had nearly twice as much lysine as ordinary maize, scientists realized that cereal grain proteins could be improved in quality by genetic manipulation. The recent discovery of high lysine mutants of barley and sorghum raises the hope that all cereals of economic importance may eventually be improved in protein quality by genetic selection.

Grain legumes, including dry beans, dry peas, pigeon peas, chick peas, and mung beans, have high protein contents and are rich sources of protein to large segments of the world's population. These proteins in general supplement those in cereal grains because they are relatively high in lysine content, with the result that when the edible legumes are consumed in conjunction with the cereal grains, a far better balanced protein diet is attained. A greater research effort is needed to improve the protein quality and quantity in food legumes.

Other plant protein sources are not fully exploited. For example, mutant types of pumpkins are known which contain seeds without a seed coat. These seeds contain over 30 percent protein and over 40 percent oil content. The quality of both oil and protein surpasses that from peanuts and soybeans. Cucurbits such as pumpkins require less water per unit of production and are adapted to arid areas.

Plant selection programs which ignore grain yield or amino acid balance and are directed solely at protein content of cereals and grain legumes could be counterproductive. Increased protein content at the expense of an essential amino acid bearing fraction may lower the overall biological value of the protein. In like manner the digestibility of the protein and its availability when used in the normal dietary pattern is an equally important consideration in product improvement; but overall yield of calories and balanced protein is the most important objective.

The biological value of a protein is the ultimate measure of its worth in human and animal diets. Protein is often not fully available, and the reasons for this are in most cases not understood. The evaluation of protein availability in these systems must be an integral part of any plant breeding program designed to affect protein quality and/or quantity. To date, biological evaluations have been limited largely to the testing of products from a research program at a time they were nearing commercial production. Biological testing capabilities in the early stages of a breeding and selection program must receive renewed attention.

Implementation

Successful genetic modification of protein quality and/or quantity can be maximized by interactions between the disciplines of plant genetics, biochemistry, human and animal physiology, human and animal nutrition, and agronomic production when members of each disciplinary area are aware of and appreciate problems of the interacting group. Progress in the successful development of nutritionally superior varieties of basic food crops could be accelerated. Integrated research in this area can be developed by the establishment of funded core projects which can, in turn, fund research in supporting project areas with each project area participating in the evaluation of the overall project.

Biological as contrasted to chemical evaluation of plant products used for food is a necessary step in any improvement program. The digestive process can be affected by composition, quantity, and competitive interactions with the various components of the heterogenous food source. While the quality of the human diet is the ultimate factor to be evaluated, animal experimentation must provide the bulk of the information. Plant breeding improvements in nutritional quality are difficult to detect unless they are associated with an easily detected chemical change. Because of the quantities of materials required for early testing of plant materials, nutritional data from existing animal systems are too costly to collect. Rapid, low feed requiring animal systems need to be developed to support and verify plant modification studies.

PROTEIN FROM OILSEEDS

Rationale

The potential protein supply for human use from present production of oilseeds is high. However, only a small fraction of these proteins is now consumed directly by humans. The major oilseeds in terms of total protein are soybeans, cottonseed, and peanuts. Other oilseed plants include sunflower, safflower, rapeseed, sesame, olive oil, palm oil, and copra.

Cottonseed oil accounts for about 10 percent of the world's edible vegetable oil production. Cottonseed meal is a largely untapped source of protein for humans; it currently goes into livestock feeds. Gossypol, a phenolic pigment that is toxic to man and some animals, is a problem in both cottonseed oil and meal. Techniques for removal of gossypol and the development of gossypol-free varieties of cotton will increase the usefulness of cottonseed oil and meal.

Sunflower seed has become the world's second most important source of edible vegetable oil and must rank high in any priority list for research attention. Sunflowers have a large unexplored genetic variability, which will allow breeders the chance to breed for particular climatic zones and environments.

Soybean oil accounts for one-fifth of total edible vegetable oil production, while soybean meal accounts for approximately one-half of total world oilseed meal production. The meal in terms of amino acid balance is of the best of the vegetable protein family. Even so, soy protein is deficient in sulfur amino acids. A modest improvement in the concentration of methionine and cystine in soybeans would enhance the value of these proteins, minimize the amount of protein that must be eaten in order to meet essential amino acid requirements, and decrease the potential hazards of overconsumption of total protein. Its use is primarily for feed of livestock and poultry. Any significant breakthrough to increase production could profoundly affect the food and feed industry of this country and the world.

Implementation

Processing technology needs to be implemented which would provide for greater and more flexible use of the by-products of oilseeds. These efforts should be coordinated with plant breeding and selection which would provide not only the maximum yield of oil but would also contain the lowest possible levels of undesirable, naturally occurring constituents.

CHAPTER 17

FORAGE AND RANGELAND IMPROVEMENT, HARVEST AND PROCESSING TECHNOLOGY

RECOMMENDATIONS

1: <u>Genetic Improvement</u>. Research should be intensified on the genetic understanding as well as the genetic improvement of forage yield, quality, adaptability, and pest resistance of important forage and range species.

2: <u>Germplasm and Seeding Technology.</u> Germplasm and seeding technology should be developed to improve rangeland productivity.

3: <u>Production Systems</u>. Forage and livestock systems should be developed that utilize the full potentials of forage, range, and livestock management capabilities to meet most economically the various nutritional requirements of animals for various physiological functions.

4: <u>Harvest and Processing Technology</u>. Harvest and processing technology should be developed that (1) increases the efficiency of use of labor and/or energy; (2) minimizes losses of biologically fixed nutrients; (3) is independent of weather hazards; and (4) increases forage output quantity and quality.

GENETIC IMPROVEMENT

Rationale

Forages (harvested forages, pastures, rangelands, silages, and crop residues) are major crops in terms of total value of production and acreage. Some 245 million hectares in the U.S. are used for silage, hay, or grazing. More than 50 percent of all feed units (corn equivalent) consumed by all U.S. livestock are derived from forages. Beef cattle and dairy cattle obtain about 73 and 63 percent, respectively, of their feed units from range and forages, while sheep obtain about 89 percent from these sources (Hodgson 1968). In most other countries of the world, ruminant livestock is even more heavily dependent on range and forages--in some countries almost completely so.

In recent years, there has been a rapid increase in the world's demand for the meat and milk of ruminant livestock. Correspondingly, the numbers of such animals have increased dramatically to supply those demands. Plentiful, cheap grain supplies were used to partially sustain animal population increases; but, in the U.S., that population increased to more than our grasslands could support. Projections are that world demand for meat and milk will continue to grow. Increasing prices have reduced the amounts of grain available for feeding cattle in the U.S., and the same situation prevails to a degree in other countries. Such pressures may well continue into the future with only occasional fluctuations.

Thus, the high dependency of ruminant animals on range and forages, the increasing demand for the meat and milk of these animals, and the current and projected reduced availability of cereal grains to feed them all point clearly to the urgent need to increase the capacity of forage lands throughout the world. There is a need for higher levels of productivity and better quality of forage crops.

Current animal populations will experience a sharp decline unless this increased range and forage capacity is achieved. While the animal population reduction is occurring, meat supplies will be plentiful and consumer prices relatively cheap. But after the reduction has run its course, meat and milk supplies are likely to be reduced to levels below needs; and in a market of scarcity, consumer prices will escalate substantially with consequential serious impacts on the nutrition of major segments of our population.

There are two principal methods of forage and range improvement: (1) genetic improvement and (2) seeding improved species into permanent grasslands. The breeding and genetic effort on forage and range species is generally low. There is no effort on some species of major importance; on others the effort may be only a very few scientist man years--well below the necessary critical mass required for reasonable progress. On few, if any, is the effort adequate to approach capturing the potential of the species. Only limited basic genetic information (considered so essential for grain crops) is available for any forage species. While it should not be construed that other potentials for improvement are not present or of considerable magnitude, the potential for genetic improvement of forage and range species is great and centers around four main thrusts.

1. Increasing the genetic potential for yield of herbage will be a basic component in increasing total production. Selection criteria for herbage yield are different from those for seed yield and not well understood. The perennial and polyploid nature of many forage and range species complicates the selection process.

2. Improving the quality of forage and range has potential for increasing performance per animal on high forage rations. Opportunities exist in such areas as (a) improving dry matter digestibility, (b) increasing animal intake potential by increasing palatability, (c) reducing lignin and silicon content, and (d) eliminating or reducing antimetabolites in some species. The potential from such efforts is indicated by one example. An improved cultivar of bermudagrass with about 10 percent increased digestibility produced a 30 percent increase in weight gain of grazing animals (Burton et al. 1967). Considerable research is needed to develop methodologies and genetic data for use in breeding for improved yield and quality.

3. Forages usually are grown on inferior sites and with a lower order of environmental control than are most annual cultivated crops. This requires a wide adaptability potential in useful cultivars and a large number of cultivars. Forage crop improvement efforts must accommodate these needs.

4. Pest resistance also offers great potential for success because of the large number of pests that attack the wide range of forage and range species and cause serious losses. In addition, perennial plants provide a year-round host for many pests and can make pest impact more debilitating.

GERMPLASM AND SEEDING TECHNOLOGY

Rationale

Overuse of many of the world's grasslands has resulted in deterioration of plant cover and productivity. Restoration of much of this important resource will require or be enhanced by improved seeding or superior natural forage and range species. The beneficial results could come rapidly, but the task is immense and should proceed without delay on the most responsive sites wherever ownership, social, or political constraints permit.

PRODUCTION SYSTEMS

Rationale

Of particular importance is the definition and application of optimum improvement and management strategies for permanent grasslands that will permit increased animal production while preventing deterioration of the resource or, in many cases, even improving it. Such activities should receive high priority for prompt and sizeable attention.

A wealth of forage and grazing management technology is available. Yet, certain cultural and use refinements will be needed as better cultivars are available and as dependence on herbage increases. Special emphasis is needed now to capitalize on the potential of innovative forage and range and livestock management practices to develop highly sophisticated production systems. These potentials should match herbage availability and quality on a year-round basis to the nutritional needs of animals for the various physiological functions of maintenance, reproduction, growth, and milk production. Similarly, there is opportunity to develop and apply animal management strategies to better use forage and range potential in different environments, types of production systems, and so on.

HARVEST AND PROCESSING TECHNOLOGY

Rationale

Large volumes of forages are harvested annually in humid or irrigated areas of the world. Harvest practices are generally labor and energy intensive, time consuming, and in humid areas subject to physical and chemical crop losses during the harvest process. It has been estimated that annual protein losses in harvesting the U.S. alfalfa crop may be equivalent to half the yearly protein intake requirement of the U.S. human population. Losses of soluble carbohydrates are also large.

Such losses mean high risk potential for harvested forages with resultant decreases in production inputs and thus lower than potential yields. Harvest technologies are needed that: (1) minimize time, labor, and energy inputs; (2) reduce losses of biologically fixed proteins, carbohydrates, and other nutritional factors; (3) are resistant to stresses from weather; and (d) increase the quantity and quality of forage output.

One approach that offers great potential but which requires more research and development is that of mechanical removal of water from the harvested forage. The process not only promises to accomplish the above aims, but also produces, from the expressed juices, a low fiber, high protein product of exceptional biological value that can be used as feed for certain high producing ruminants or monogastric animals or as a valuable new source of protein for humans. This concept offers great promise for simplification in technology and scale and, for that reason, for rapid adaptation to many developing nations.

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SECTION IV:
LIVESTOCK, POULTRY, AND FISH PRODUCTION

INTRODUCTION

Animal products comprise significant portions of the food supply in the U.S., supplying two-thirds of the protein consumed, one-third of the energy, one-half of the fat, four-fifths of the calcium, nearly two-thirds of the phosphorus, and significant quantities of essential minerals, micronutrients, and vitamins. The amino acid composition of animal proteins is of high biological value to man. In some countries, animal products supply much smaller proportions of the diet; in others, the dependency on animal products, especially fish, is much greater than in the U.S. Further, a high proportion of people prefer to eat animal products. The production, processing, transportation, and marketing of these products provides employment for a large segment of the population of the U.S. Thus, the viability of the livestock industry is of significant economic importance to the country.

Ruminants can convert cellulosic or concentrated feeds to food, while monogastrics require concentrated feeds for the most part. For most of man's history, and even today in much of the world, domesticated animals have consumed feedstuffs not usable by man--fibrous plant materials and the wastes. In recent times a few countries, including the U.S., have achieved the capacity to produce cereal grains, especially maize and sorghum, in quantities in excess of food needs. Livestock has played a significant role as a residual user of surplus feeds. Prices have been low enough to make such grains important animal feeds, and animal productivity has increased. But within the past few years world demand for all grains, both as food and feed (together with changes in world market structures), have resulted in price increases. As a result, a new look is being taken at the use of grain, improved forages, crop residues and by-products as ration constituents.

A large part of the earth's land surface can only infrequently produce cultivated crops directly usable by man, but it can produce high cellulose plant material that can be converted economically to food only by animals. Other land, that could regularly produce food crops, finds its greatest economic value in producing forages. Also, most plant food crops produce large volumes of cellulosic residues usable by ruminant animals. Rangelands are one of the world's greatest untapped sources of feed for livestock, and improved rangeland management could greatly enhance food production. (See Chapter 17, Forage and Rangeland Improvement, Harvest and Processing Technology.)

The world livestock population exceeds the human population by two to three times. The number of ruminants (cattle, buffalo, sheep, goats, and camels) alone approximates the human population of 3.5 billion, and there are about 0.6 billion swine and 5.3 billion poultry. Livestock constitutes a storehouse of food available to man, reducing his vulnerability to periods of poor crop production.

It is important to emphasize that increasing livestock productivity is dependent upon improving the total food production system.

CHAPTER 18

REPRODUCTIVE EFFICIENCY

RECOMMENDATIONS

1: Reproductive Diseases. Research is needed on reducing losses and controlling diseases during gestation or incubation.

2: Number and Sex of Progeny. Studies are needed on increasing the number of progeny per breeding female as well as on the sex control of the progeny.

3: Genetically Superior Animals. Research is needed on increasing the reproductive capacity of selected genetically superior mammalian animals and on estrus synchronization of females for insemination.

REPRODUCTIVE DISEASES

Rationale

The first step is to control diseases causing abortion in mammals, hatching failure in poultry, and male or female sterility. Much of the technology to detect such diseases and substances that cause abortions or infertility and to control them within economic levels is available, but much basic research is still necessary to gain sufficient understanding for their control. The second step is management for reproduction and providing breeding females with essential nutrients. For example, it is well documented that in some areas of the tropics, provision of the minimum essential levels of the phosphorus in supplemental feed to cattle on deficient pastures has raised the calving levels.

Constraints on the reproductive efficiency of animals result from improper breeding management, infections, toxic diseases, and nutritive deficiencies. Procedures should be developed for early and rapid diagnosis of incipient infertility, and for the determination of the etiology, incidence, and control of diseases, toxins, and deficiencies which induce male or female infertility and cause abortion or stillbirth, or the birth of defective offspring. Infectious diseases include brucellosis, vibriosis, leptospirosis, foot and mouth disease, and many others; toxins involved include the mycotoxins of moldy feed. Many nutritive deficiencies affect reproduction, of which insufficient phosphorus intake, for example, is well known. Some control measures are already known and others should be developed for all of these.

NUMBER AND SEX OF PROGENY

Rationale

Techniques for increasing the number of progeny produced by each female reduce the cost of maintaining the breeding herd or flock, but technical skills and materials required may not decrease the basic cost of each progeny. Thus, economic studies are needed. Areas of research should include:

(a) increasing the number of young produced from each gestation: for example, increasing litter size in swine, the incidence of twinning in cattle, and of twins and triplets in sheep and goats; amd

(b) shortening the gestation interval by terminating gestation at optimum periods and still allowing satisfactory offspring survival: the objective is to increase the number of gestations per lifetime of each female.

For some purposes control of the sex of the progeny would be economically and genetically advantageous. Conflicting results are reported for the techniques employed, but much more research is necessary to make the process feasible.

GENETICALLY SUPERIOR ANIMALS

Rationale

Studies are needed on how to rapidly increase the number of genetically superior animals by (a) hormone treatments to induce multiple ovulation, (b) artificial fertilization, (c) removal of embryos to "incubator females" for gestation, and (d) reduction of periods of reproductive quiescence in genetically superior females.

Artificial insemination, which is a long established and viable technique for increasing the number of progeny from genetically superior males, is an expensive technical service. The costs could be reduced in this procedure and in management of parturition and of resulting newborn if optimum numbers of females at each farm unit could be bred in one short interval.

CHAPTER 19

IMPROVED EFFICIENCY OF LIVESTOCK PRODUCTION

RECOMMENDATIONS

1: Genetic Improvement. Research is needed on genetic selection of animals with desirable production traits including rapid growth, efficient feed conversion, high production per animal, and disease resistance.

2: Nutrition Efficiency. Research on nutrition efficiency should be carried out on nutritional requirements, use of nonprotein nitrogen, rumen bypass, greater use of forage, and unconventional feedstuffs.

3: Disease Prevention and Control. Research should be increased on disease prevention and control, such as systems to reduce prevalence of disease, detection and elimination of carriers, nature of defense mechanisms, and drugs and chemicals for control of diseases.

GENETIC IMPROVEMENT

Rationale

Artificial insemination in dairy cattle has permitted highly effective selection on males (from one male per five to twenty females, to one male per three thousand or more females). This, coupled with precise mathematical studies of records of related females, has permitted marked improvement in milk production (doubling of the average milk yield of American dairy cattle in five generations) and reduction of the national breeding herd from about 25 million to about 11 million milk cows. For poultry the time required to produce a broiler has been reduced from 14 weeks to 8 weeks, with feed efficiency being increased twofold (4 kg feed/kg broiler to 2 kg feed/kg broiler).

Crossbreeding has wide potential applicability for improving production. Crossing of widely divergent lines often leads to increased survival and vigorous growth of the progeny and increased feed efficiency, which results in increased production of human food from a fixed breeding population. But to achieve this, an investment is required in a scientifically oriented system of providing the necessary inputs to manage, feed, and garner the harvest from the improved progeny. It is also necessary to maintain breeding herds with resistance to disease, parasites, and stresses of climate and environment.

The necessary steps involve: (a) description of the characteristics desired; (b) measurements of such characteristics in a standard manner, to reduce variation due to environment; (c) determination of the heritability of the desired characteristic; (d) generation of means for rigorous selection for the characteristics; and (e) implementation of the operation on a broad scale.

NUTRITION EFFICIENCY

Rationale

Quantitation of nutrient requirements is a complex area of research, because of the variety of factors that influence requirements, the criteria for nutritive adequacy, and the variability within and among animal species. Continued changes in breeding, management, and introduction of new feedstuffs and methods of feed processing bring with them new factors or introduce extreme situations that influence nutrient metabolism and requirements; hence, there is a continuing need for reevaluation. For example, deliberate alteration of the gene pool of a meat-producing animal species to attain greater production and more desirable carcass characteristics may influence specific nutrient requirements in as yet unknown ways. This fact is well recognized in poultry, in which strain differences are known to influence arginine, zinc, manganese, and riboflavin requirements. What is the extent of variation in specific requirements within other animal species? Is it feasible to employ selection techniques to develop strains with lower nutrient requirements? Many problem areas where research should be implemented were identified by the NRC Committee on Animal Nutrition (NAS 1974). Four of the most important are discussed below.

1. Define Nutritional Requirements for Optimal Production and Optimal Use of Feedstuffs

In our knowledge of nutritional requirements of animals there are many gaps that must be eliminated before optimal use of feedstuffs and optimal animal production can occur.

2. Improve Use of Nonprotein Nitrogen (NPN) Sources

Ruminants, through their ruminal microorganisms, can use NPN compounds to synthesize body proteins and convert these proteins to milk, meat, and fiber. Basic research on the biochemistry and physiology of NPN use is needed to improve the efficiency of NPN use by ruminants, and to a lesser extent, by non-ruminants.

3. Develop Rumen Bypass Technology to Improve Amino Acid Use

This is an area of research that could increase the efficiency of feed use by ruminants. Preliminary studies indicate that certain amino acids may benefit ruminants, particularly at high levels of productivity, if they are treated so that they bypass the rumen (preventing bacterial degradation) and become available in the fourth stomach and lower intestinal tract.

4. Develop Systems for Greater Forage Use

Ruminants can digest fibrous feeds which humans do not eat and cannot digest. Most of the forage ruminants consume is grown in land areas where the best and sometimes only use of them is in forage production. Approximately one-half of the land area in the U.S. produces forage. Therefore, ruminants are important in converting inedible forage into animal protein.

As grains and other feeds are increasingly consumed directly by humans, more forages and unconventional feedstuffs will be used in the rations of all animals. Research is needed to develop rations, as well as management and production programs, which make use of different forages at varying levels of intake.

Special emphasis should be given to the following:

(a) Develop improved forage preservation methods and delivery systems. Development of organic acids by bacterial breakdown of carbohydrates is a classic method of feed preservation. Direct addition of organic acids is being used to preserve forages, offering possibilities for eliminating molds and for increasing the feeding value of forages. Other additives and treatments have also been used to decrease ensiling losses and to improve silage quality. Improved methods of ensiling, dehydration, and other methods of handling forages will increase their feeding value and use and decrease nutrient losses.

(b) Improve crop residue utilization by chemical, physical, or other treatments. The feeding value of high fiber crop residues (e.g., straws, corn stalks, and low quality forages) can be increased by chemical treatments, such as the process developed in Germany involving the use of sodium hydroxide. These treatments would increase the digestibility of cellulose, hemicellulose, and other nutrients, thereby enhancing their value. Physical treatments, such as pelleting, are especially helpful in increasing the palatability, intake, and feeding value of low quality, high fiber feeds.

DISEASE PREVENTION AND CONTROL

Rationale

Diseases retard maturity, decrease feed efficiency, increase overhead costs, and result in wastage from condemnation. This results in the loss of at least one out of every ten animals each year in the U.S. An unanticipated temporary impact of the highly effective control of one disease of poultry, Marek's disease, with the introduction of a vaccine was the depression of the market price caused by rapid overproduction resulting from increased survival. This situation has developed into decreased costs of poultry production to the benefit of both producer and consumer. Many of the discoveries of methods for controlling diseases of livestock and poultry have been applied to the control of disease in humans.

Implementation

Research emphasis should be given to the following areas:

A. Eradicable Diseases

Some preventable diseases have been eradicated in many nations, but they remain as primary constraints on livestock productivity in many agriculturally developing countries. Consequently, they have led to the imposition of quarantines that seriously restrict international commerce. A report by the American Veterinary Medical Council (AVMC) in 1974 showed that systems that were successful in ridding the U.S. of foot and mouth disease, babesiosis (Texas cattle fever), vesicular exanthema, and exotic Newcastle disease, and in reducing brucellosis, tuberculosis, screwworm, and hog cholera to rare infections can be applied to developing nations. To protect the U.S. against reestablishment of these plagues, to assist other nations in eliminating these diseases, and to make possible the eradication of other infections enzootic to the U.S., three research objectives should be satisfied:

1. identification of diseases and their epidemiologies;
2. creation of systems that reduce the prevalence of disease to a level that makes eradication feasible, such as the development of effective vaccines and methods of environmental management; and
3. development of methods that will detect and eliminate carriers and vectors of disease so that effective quarantine can be established and maintained.

Before the usefulness of a method can be fully evaluated, the findings from the fundamental studies required to achieve the three research objectives must be applied to specific diseases in specific hosts, first under controlled conditions and later with field conditions under adequate supervision.

The primary criterion for selection of subjects for applied research should be the identification of a specific disease for an official control program. The establishment of an official program should be made only after the above research objectives have been satisfied.

B. Diseases with Complex Etiology

The major unsolved disease problems in intensively reared livestock are the result of interaction of one or more pathogens with the stressor effects of environment or crowding on host animals. In this group we find many of the neonatal diseases, all of the diseases associated with animal transport, and many of those found in large dense populations.

Fundamental research is needed on: (1) the nature and inheritance of innate defense mechanisms of livestock and poultry species, (2) methods of effectively stimulating specific immunity, and (3) the contributions of environmental and behavioral stressors on the susceptibility of animals to disease. This research will require federal funds not now available for staff and materials, and for sophisticated and expensive environmental facilities, such as high temperature and controlled humidity chambers.

Applied research is needed on neonatal diseases of swine and cattle and on respiratory and enteric diseases of swine, cattle, and poultry.

C. Diseases Controllable by Drugs and Chemicals

Diseases in this group, caused by parasites and certain bacteria, contribute in a major way to the loss of efficiency in feed conversion and to lesions that are a significant cause of condemnation. Drugs and chemicals, while often effective, are expensive if used at high levels and may leave undesirable residues in meat, milk, or eggs if improperly used. Research is needed that will: (a) reduce the requirement for high level use of chemotherapeutic substances by developing management systems that reduce the exposure to parasites; (b) breed for increased resistance of the animal to parasites; and (c) develop drug regimes that will provide adequate protection against parasitism without leaving drug residues.

The second of these objectives would require the systematic study of the potential for breeding animals for disease resistance. It may necessitate the assembly, preservation, and inventory of gene pools of food animal species for factors that determine resistance to disease. The long-term costs of controlling disease in terms of labor, drugs, and food safety justify serious consideration of breeding for animals resistant to disease.

CHAPTER 20

PRODUCT QUALITY AND CONSUMER ACCEPTABILITY

RECOMMENDATIONS

1: Human Health. More emphasis should be placed on studies on the effect of animal products on human health.

2: Fat in Beef and Pork. Feeding, management, and production programs should be developed for decreasing excess, trimmable fat in beef and pork.

3: Safety in Foods. Criteria should be developed for determining biological safety in foods.

HUMAN HEALTH

Rationale

Much is still to be learned about the relationship of animal products, saturated fats, and cholesterol to heart disease. It is still unclear whether dietary changes, such as substituting unsaturated fats for saturated fats, can significantly reduce cardiovascular problems. Feeding diets high in saturated fatty acids to experimental animals over a long period of time indicates that serious problems may develop. It has been demonstrated that the linoleic acid (unsaturated) content of milk, eggs, and body fat can be increased by dietary control of farm animals. But before this is recommended to the farmer it should first be demonstrated that it is advantageous to human health to do so. Moreover, scientists need to determine whether animal products containing unsaturated fats will be accepted by the public as readily as those with saturated fats.

Studies are needed on the effects of feeding products at varying levels and for varying periods of time to experimental animals, and on the application of these to human health.

FAT IN BEEF AND PORK

Rationale

Much of the beef and pork produced in the U.S. is fatter than the consumer wants. Thus, grain and other energy feeds are being wasted by overfinishing cattle and swine.

Approximately 20 percent of excess fat is trimmed in choice beef carcasses. In 1973, the resultant waste amounted to a $1.15 billion loss which was ultimately absorbed by the consumer (NAS,in press).

Similarly, nearly 90 percent of the barrows and gilts marketed in the U.S. have more separable fat than lean in their carcasses, leaving only 10 percent to grade USDA number 1--the only grade with more lean than fat. Similarly, the waste fat content of the approximately 14 billion pounds of carcass pork produced annually in the U.S. could be reduced by 5 percent. An increase in the lean and decrease in the waste fat by 5 percent would result in a saving of $0.5 billion per year in lower feed costs.

SAFETY IN FOODS

Rationale

As new feed additives, animal wastes, by-product feeds, and alternative feed sources are used, the possibility of harmful residues occurring in animal products needs to be guarded against.

Research is required on procedures that could safely salvage for human consumption animal protein that would otherwise be destroyed to eradicate animal diseases.

It is recommended that more adequate methods be developed for determining the biological safety of foods for human consumption. A concept of biological zero should be established with regard to residues in food. This would be defined as the level which a panel of competent scientists, after examining adequate data, would determine as having no harmful effect on humans.

CHAPTER 21

FISH PRODUCTION

RECOMMENDATIONS

1: Wild Stocks. A research program should be implemented to increase food production from wild stocks of fish, including the increased harvest and efficiency of underutilized species. The creation of a national fisheries management regime should also be undertaken.

2: Aquaculture. Support should be given to the development of technological and scientific bases for aquaculture, and pilot plants and culture systems should be developed in conjunction with industry.

WILD STOCKS

Rationale

Concern that society has generally failed to conserve and allocate fisheries resources in an effective manner under existing institutions (both domestic and international) reflects a lack of centralized policy for fisheries management in the U.S. and a lack of coordinated, effective management. In the U.S. this is a consequence of historical practice whereby the states were given responsibility for and authority over fisheries management out to the limit of territorial waters, while the federal government had no authority except where international fisheries were involved. The fragmentation of authority and management and the general lack of cooperation among states for the regulation of fish stocks that cross state borders have made it difficult to implement workable management programs within state waters.

It has also been a tradition in this country that resources of marine fish are available to all, with the result that no limit could be placed on the number of boats allowed to engage in a fishery. The outcome has been exploitation and overcapitalization, in many cases seriously damaging the stocks biologically and wasting labor and financial resources. Other natural resources have not faced this handicap in the U.S., nor is this practice common to many of the other principal fishing nations. It will be necessary to alter the system eventually, and an opportunity is offered to make the change now when the U.S. is being obliged by international events, including the Law of the Sea Conference, to make significant changes in its national fishery policies.

In the field of international fisheries conservation, the U.S. has relied on international commissions and bilateral agreements to control fishing and to protect stocks. To varying degrees, none of these arrangements has been fully satisfactory, principally because insufficient authority has been given to the management bodies. As a consequence, some international fisheries stocks have been damaged--in some cases perhaps irreparably.

Implementation

There are three ways to increase the production of protein from wild stocks: (1) use species not being used, or only partially used; (2) develop more efficient systems of recovery of protein in harvesting and processing; and (3) develop effective management. These three ways are discussed below.

1. Underutilized Species

The present world catch of marine fish and shellfish is about 60 million metric tons per year, according to data supplied by the Food and Agriculture Organization (FAO). FAO estimates of the potential world catch of conventional species are from 100 to 115 million metric tons. If unconventional species such as krill and lantern fish are included, the potential is much larger. In U.S. coastal waters the current annual harvest by U.S. and foreign fleets is 5.5 million metric tons, from statistics provided by the U.S. National Marine Fisheries Service (NMFS). NMFS estimates that this could be increased to at least 8.6 million metric tons.

2. More Efficient Recovery

Greater use of fish could be achieved through more efficient recovery from current harvests. For example, flesh-separating machines which squeeze the flesh from the skin and bones of fish and pass it through perforations on stainless steel plates may increase the useable yield by as much as 40 to 50 percent. Fully automated mechanized methods would also maximize cost effectiveness. Information dissemination and research can help to greatly reduce the present waste of fish protein through spoilage. Preservation techniques should be taught to fishermen and others in the coastal communities.

Other gains can be achieved through increased human consumption of fish now used for industrial products (principally fish meal) and through the use of species that are discarded at sea by developing new products, such as minced fish, and alternative methods of shipboard preservation.

3. Effective Management

Better management is required to prevent the overfishing or the economic extinction of traditional stocks of fish. Sometime in 1976, the U.S. will probably assume some form of extended jurisdiction over the coastal fisheries resources out to 200 nautical miles from its shores. This will give us the first opportunity in our history to create coordinated and effective conservation measures in both domestic and international fisheries. The enormously increased areas over which the U.S. will exercise exclusive fisheries jurisdiction (approximately 2,222,000 square nautical miles of continental shelf and the overlying water) contain the largest fisheries resources of any nation in the world. This area has an annual potential production of at least 8.6 million metric tons of fish for food and recreation, more than 10 percent of the current world production. Other coastal nations will be offered the opportunity to apply conservation management to large areas of ocean off their coasts.

The U.S. is thus obligated to reexamine its national policy because for the first time it would be responsible for managing the fisheries resources within a 12 to 200 mile zone. This obligation is a consequence of events that have taken place in this country and around the world in recent years altering domestic and foreign attitudes toward the rights to fisheries resources and their conservation. Many other countries will also be reexamining their fisheries management policies.

AQUACULTURE

Rationale

World aquaculture production is 6 million metric tons (8.6 percent of seafood supplies). In the past five years production from aquaculture worldwide has doubled, and the proportion it produces may be as much as 10 percent of the world's aquatic-derived foods. In the U.S. the 1973 production of fish was 2,136,000 metric tons, of which 73,000 metric tons were produced by aquaculture; total U.S. consumption of fisheries products is about 3.2 million metric tons. Thus, aquaculture produces about 3.4 percent of U.S. production and a little over 2 percent of the supply. Because of the existence of very extensive areas of suitable aquatic habitat and the availability of proven technologies for several species, the potential exists for significant increases in fish production by culture, especially in the estuarine and marine environments.

Although aquaculture has been slow in developing, fish farming on a small scale has existed for a long time; and the desirability of expanding its scope and production has been recognized, both by those engaged in the culture of such species as oysters, catfish, and trout, and by those attempting to develop industries for shrimp, mussels, and their products. In recent years in particular, there has been high interest in aquaculture and increased activity, during which government, academic, and industrial groups have engaged in aquaculture research and development. In many cases results were encouraging, but in others they fell short of expectations. Moreover, many of the problems, some of which had seemed near solution, proved intractable, often for economic reasons.

Aquaculture development in the U.S. has therefore stagnated. While biological and technological information and culture methods are available to increase production of salmon, trout, catfish, oysters, and some species of clams, development of viable aquaculture of most other species will require research to provide adequate biological and technological bases and to develop and test culture systems on a pilot scale. Only then will private capital be attracted that will lead to the establishment of an industry. Much of this research, because of its nature and cost, should be performed by the government or by other research groups with government funds.

Expanded aquaculture also requires unpolluted coastal or estuarine areas or supplies of high quality fresh water, but other users also want these limited resources. Where such problems cannot be resolved, closed systems will need to be developed, thereby releasing aquaculture from dependence on natural water supplies and expensive waterfront property.

Urgent research areas on fish culture include:

(a) Research on methods of increasing supplies of seed (eggs and larvae). This research should include reproductive physiology to develop the ability to induce maturation and spawning in captivity and for the development and maintenance of brood stocks. This is also a necessary prelude to genetic modification and selective breeding.

(b) Research on nutrition of cultured animals including larval stages, and on the development of inexpensive and nutritionally effective feeds.

(c) Research on disease control of hatchery fish and shellfish production. With the high density populations that result from intensive culture, disease incidence and severity increase markedly. Information on disease prevention and control is presently insufficient for cultured species.

(d) Research on the nature of institutional and related constraints on aquaculture development and on methods of technology transfer.

Implementation

The federal government has an essential role to play in encouraging expansion of aquaculture. Private aquaculture in the U.S. is based primarily on systems developed and research conducted or sponsored by the federal government. Commercial salmon and trout culture became possible following government research and development for public hatchery programs, which solved problems such as nutrition and disease control. In 1954, 1.4 million pounds of trout were produced in private fish farms; in 1973, production was about 60 million pounds. Techniques for commercial rearing of salmon, recently developed in government programs, has started a new industry and about 10 companies are engaged in commercial salmon farming. In recent years the oyster culture industry has been strengthened by research in government laboratories on hatchery production of young.

The importance of the federal government role in aquaculture is greater now than it will be in future years, since much basic and essential information is currently lacking and the industry is small. The appropriate role of the government now would appear to be to conduct long-term research, much of which is highly technical, requiring specialized equipment and the multidisciplinary approach of highly trained scientists, engineers, and economists. These kinds of expertise are unavailable to industry at the present stage of aquaculture development. Later, when a larger and better organized industry exists, it can assume much of the government's responsibility.

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SECTION V: FOOD SCIENCE AND TECHNOLOGY

INTRODUCTION

Primitive man had to forage for food in his natural environment, feasting in times of plenty and starving in lean times. Gradually he learned the technology of food preservation and improved his ability to save plentiful foods for later use in time of shortage. In developed countries, food science and technology have done much to relieve the impact of hunger and malnutrition, but many developing countries do not enjoy such benefits. There the seasons still alternate from wet to dry or cold to warm, bringing the same stresses on man's food supply as in prehistoric times.

The major goals of the food system other than food production can be listed as follows:

1. to maximize the availability of high quality, safe, nutritious foods at the least cost to consumers;
2. to improve the efficiency and dependability of food delivery systems;
3. to reduce food losses in distribution and storage;
4. to reduce resources needed in protection, storage, and distribution of food; and
5. to determine the comparative advantages of food production and distribution systems to minimize total inputs and maximize total outputs.

Because of consumer concerns and government actions, food processors must be concerned, not only with the production of wholesome, safe foods, but also with pollution aspects of their process, with nutritional value, and with shelf life of the product. Pollution concerns not just industrial waste, but packaging as well and its effect on eventual solid waste disposal. Connected to this is the ecological problem of power and water use.

Processing and preservation technology is aimed at storage stability of foodstuffs including packaging. The major issues involved are the safety of the food supply from pathogens, the maintenance of quality (i.e., no chemical or microbial decay), the prevention of losses from insects, and the maintenance of nutritional value.

The primary principles of processing include the destruction of harmful microorganisms by sterilization, pasteurization, or blanching; separation processes, such as membrane processes, extraction and immobilized enzymes; environmental, temperature, and gaseous atmospheric control; chemical preservatives, fermentation, and/or alkali preservatives and additives; and control of water-dehydration, intermediate moisture foods, and freezing.

The prime generic function of a commercially viable package is protection of the contents. Considerations in packaging research are energy and resource conservation needs, such as prevention of loss of foodstuff, quantity of packaging material, energy to create packaging material, and disposal or secondary use of used packaging materials. Other considerations include consumer acceptance, cost to the consumer, and the relationship of packaging technology to a large system of processing and preserving foods.

Flexible pouches and thin-walled drawn containers with heat sealed lids for heat stabilized foods are being developed and show promise. They eliminate refrigeration; costs of material compare favorably with metal cans and their weight is about 10 percent that of cans; empty-container storage needs are fewer; and in the opinion of many food technologists, the products surpass frozen and canned foods. However, pouch output is slow and labor intensive, capital investment is high, and pouched products containing meat or poultry have not received USDA approval.

The evaluation of new potential sources of food is particularly important in future development. Some important critieria are: increased growth potential, greater biological value in human nutrition, freedom from vicissitudes of weather, higher yields per unit area, utility in food formulation, and economy.

CHAPTER 22

LOSSES IN THE FOOD SYSTEM

RECOMMENDATIONS

1: Losses of Raw Product. Research must be increased to reduce losses during harvest or slaughter, handling, and storage of raw product.

2: Losses of Prepared Product. Research must be increased to minimize losses due to stress in packaging, storage, transportation, and distribution of processed foods.

LOSSES OF RAW PRODUCT

Rationale

Rapid and large increases in available food supplies can be achieved by reducing losses incurred during harvest, slaughter, handling, and storage of the raw product. In addition, an effective reduction in losses and consequently an increase in yields represents a major conservation in energy. Inherent in the increased availability is also the potential for enhanced nutrient availability and consumer acceptability of the product.

Implementation

To reduce losses during harvest, slaughter, handling, and storage of the raw product, the following are recommended as major steps:

1. improve harvesting, slaughter, and handling systems;
2. expand knowledge of postharvest and postslaughter physiology;
3. increase knowledge of microbiological growth and control of toxicity;
4. improve pest control; and
5. evaluate the significance of the chemical activity of water in storage.

LOSSES OF PREPARED PRODUCT

Rationale

The segments of packaging, storage, transportation, and distribution compose another area of our food system in which significant increases in availability of food supplies can be achieved through reductions in loss. Stress, the major cause of these losses, consists of primary and secondary factors which in most instances are additive. Stress, which occurs in each segment of this area, is usually initiated by mechanical or environmental effects (primary factors) which then induce chemical, biochemical, and biological effects (secondary factors). For example, mechanical stress can result in broken grain, bruised fruits and vegetables, or ruptured packages. Mechanical stress breaks down the protective barrier, be it natural or artificial, and allows chemical or biochemical reactions or microbial and pest invasion to destroy nutrients and consequently lower quality and acceptability. Environmental stress, such as significant changes in temperature, light, or atmospheric conditions, can induce chemical and biochemical reactions (e.g., enzymatic or nonenzymatic brownings) which destroy the quality of the product with or without permeating the protective barriers. Environmental stress can also produce physical, chemical, and physiological changes which create optimum conditions for loss due to microbiological proliferation and development of toxins.

In addition, stress in one segment of the packaging, storage, transportation, and distribution area may induce loss in another segment. Stress, therefore, must be critically evaluated in a total system, ranging from harvest to consumption. In this way, the purpose of increased availability of supplies through reductions in loss can be achieved with a minimum of effort in each segment.

CHAPTER 23

FOOD PRESERVATION AND PROCESSING

RECOMMENDATIONS

1: Food Composition and Chemistry. Research must be expanded to increase our fundamental knowledge of food composition and chemistry.

2: Food Composition and Quality Assurance. Research and development are needed on rapid and quantitative methods of detection of food components and hazards associated with foods and their toxicological significance.

FOOD COMPOSITION AND CHEMISTRY

Rationale

The development of the technology of food preservation and processing has evolved slowly. Significant improvement in the efficiency of current operations and the safety and quality of products cannot be achieved without a significant increase in our knowledge of food composition and chemistry, and without attention to types of waste and proper use of waste within the total farm-to-processor system.

This knowledge base is also essential to the further development of food fabrication processing, i.e., the conversion of food components--carbohydrates, lipids, proteins, vitamins, and minerals--into products for the consumer. The process may become essential in meeting the world's need for food. But only with the processor's adequate knowledge of the composition and chemistry involved can the quality and safety of the products be assured for the consumer.

Implementation

Primary emphasis for research on food composition and chemistry should be placed on the following areas:

1. knowledge of the native structure and composition of plant and animal materials and the physical-chemical interactions of food components;

2. knowledge of the effects of preservation and processing on the nutrients and physical-chemical interactions of food components; and

3. ways to minimize generation of waste and maximize use of waste.

FOOD COMPOSITION AND QUALITY ASSURANCE

Rationale

Food composition and quality assurance are tangible terms which can be measured and related to set standards for various foods. Food safety is an abstract term and cannot be measured: it is the absence of hazard. The most fundamental problem in the area of food safety is that of quantifying hazards associated with foods. The critical problem area lies in determining, in a raw or processed food, the presence and extent of hazard which is either naturally present in the food or a by-product of processing. The second major problem in the area of food safety is that of establishing permissible levels of hazardous substances on the basis of scientifically defensible criteria. Extrapolation of toxicological, teratological, and/or oncological data from animals to humans is subject to debate. Exposure to zero levels of carcinogenic or toxic substances is scientifically untenable, thus scientific criteria for these substances must be established.

There are six major classes of hazard in foods:

(1) food borne diseases of microbiological origin;
(2) malnutrition;
(3) environmental contaminants;
(4) naturally occurring toxicants in foods;
(5) pesticide residues; and
(6) food additives.

Hazards 1, 3, 4, 5, and 6 can occur with a high rate of frequency; therefore, rapid, quantitative methods of detecting these hazards and their toxicological significance are needed, and their development should be given priority.

Food composition and quality assurance of raw and processed foods are dependent on measuring the constituents of foods and their nutritional value chemically or microbiologically. The most important need in this area is the development of rapid, quantitative methods for the determination of protein, fat, carbohydrate, moisture content, water activity, vitamin and mineral content, dietary fiber, protein quality, heavy and trace mineral content, and the presence of intentional or unintentional food additives.

It is also important to support research which will determine the biological availability of the nutrients in raw and processed foods, as well as identification of processing conditions which affect their biological availability during processing, distribution, and storage.

Finally, such an encompassing research effort will create a problem unless computer technology (both hardware and software) is developed to provide analytical systems to collate, calculate, interpret, and evaluate the research data.

Implementation

The feasibility of developing a program to measure composition, quality assurance, and safety of our food supply from harvest or slaughter through consumer use is dependent upon three major points: (1) development of a useful computer storage and retrieval system for current and future scientific data; (2) federal support of research on food science and human nutrition in governmental agencies and universities; and (3) communication of this information to the public. This program will require a sizeable commitment of federal dollars.

CHAPTER 24

DISTRIBUTION AND TRANSPORTATION

RECOMMENDATIONS

1: The Packaging System. Research and development is urgently needed on standardization of our packaging system to improve handling in distribution.

2: National Transportation Plan. Research is needed for the development of a more detailed national transportation plan as it affects agriculture.

THE PACKAGING SYSTEM

Rationale

The cost of distributing food and food products represents about half of the total cost of most food products. Many of the inefficiencies in materials handling can be traced to an industry pattern in which product variety was deliberately created to appeal to special buyers. More than 1,400 different container sizes are used by the fruit and vegetable industry alone. Apples are now packaged in 40 different shapes and sizes, none of which will fit the standard grocery shipping pallet. The lack of standardization in packaging is a serious obstacle to efficient materials handling and distribution. In certain instances, however, for the convenience of the consumer the packaging of the same product in a size that is enough for two servings, for one serving, or for a family of six, may serve a valuable purpose.

Ideally, goods should be packed in cartons of standard dimensions that fit on a single-sized pallet, which in turn fits into standardized containers, railroad cars, and trailers.

Implementation

There should be a complete review of the possible sizes and shapes of all the various containers, packages, pallets, and transportation vehicles to determine the changes that would optimize distribution economics. The benefits and disadvantages of each pattern of standardization need to be carefully weighed. Industry participation in this endeavor is essential.

NATIONAL TRANSPORTATION PLAN

Rationale

Transportation is a limiting factor in every part of our food system. Agriculture is pursued where the land is productive, but this productivity has no necessary relationship to the location of the ultimate consumer. The food system, therefore, is more dependent on transportation than most other parts of our economy.

The rural railroad network has disintegrated as railroads have abandoned tracks that were not profitable. The rural highway system has not been improved sufficiently to take the heavy loads that were previously handled by rail. The problem is aggravated by transportation regulations, such as "tariffs" that define a set of conditions under which a shipper can ship goods, and the rates that will apply to those shipments. This allows only a portion of this already inadequate transportation system to be used in moving goods into the rural communities.

From a long-range viewpoint, the food system cannot ignore the greater fuel efficiencies of moving foods by water and rail rather than by truck. We need to develop a transportation system that optimizes the flow of goods with a minimal expenditure of petroleum. This will require coordination of the regulatory powers of various agencies toward the common goal of a more efficient system.

In the near future, however, improvements must be effected within this transportation system as it now exists. Such improvements will, of necessity, be made within one mode of transportation at a time. In view of the overall transportation plan, any action that is taken to increase the efficiency of railroads must be coordinated with corresponding necessary ICC regulations concerning changes in our truck system to realize the greatest overall gain in transportation efficiency (Miles 1974).

Implementation

To design a more detailed national transportation plan as it affects agriculture, it is essential to know what commodities are being moved, in what quantities, between what points, and at what cost. It is important to know the relationship of the flow of agricultural products to the flow of other types of commodities and the way in which this interaction relates to the aggregate capacity of barge, rail, and truck transportation.

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