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NEW DIRECTIONS FOR AGRICULTURE: THE SCIENCE AND TECHNOLOGY OF THE FUTURE

HEARING

BEFORE THE

JOINT ECONOMIC COMMITTEE
CONGRESS OF THE UNITED STATES

NINETY-EIGHTH CONGRESS

SECOND SESSION

OCTOBER 2, 1984

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JOINT ECONOMIC COMMITTEE

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TUESDAY, OCTOBER 2, 1984

NEW DIRECTIONS FOR AGRICULTURE: THE SCIENCE AND TECHNOLOGY OF THE FUTURE

TUESDAY, OCTOBER 2, 1984

CONGRESS OF THE UNITED STATES,
JOINT ECONOMIC COMMITTEE,
Washington, DC.

The committee met, pursuant to notice, at 10:10 a.m., in room SD-106, Dirksen Senate Office Building, Hon. James Abdnor (member of the committee) presiding.

Present: Senators Abdnor and Symms.

Also present: Dale Jahr and Robert J. Tosterud, professional staff members.

OPENING STATEMENT OF SENATOR ABDNOR, PRESIDING

Senator ABDNOR. The committee will come to order.

We do have an exciting morning before us and I will make my opening remarks very brief. Before I do, I want to pass on the regrets of the chairman of this committee, Senator Jepsen. He has done a commendable job of bringing agriculture's future before this committee and has had some astounding and excellent testimony. Of course, none are more anxious to hear this panel we have before us.

I want to first thank you for the effort that you made to share your views with the committee and Congress on the subject of New Directions for Agriculture: The Science and Technology of the Future. I extend a very special thanks to the Council for Agricultural Science and Technology which today unveils its report requested by this committee about a year ago. The title of this report is "Development of New Crops: Needs, Procedures, Strategies, and Options." Great appreciation is also extended to the Office of Technology Assessment which has agreed to give this committee a preview of the status of its project, also requested by this committee, "Technology, Public Policy, and the Changing Structure of American Agriculture." We are anxiously awaiting that report.

For 280 consecutive years American farmers and ranchers have brought before and laid before their fellow citizens the sustenance of this Nation's security and freedom: Food, clothing, and shelter. Something that no country can do without. Only because of our agriculture's consistency can we brag of past accomplishments and dreams of new frontiers. All achievements and expectations, no matter how grand or worthy, including democracy and peace, become absolutely meaningless when confronted by a famine and mass starvation. Our farmers and our national agricultural scientific resource base have always been and remain today the country's first line of defense. Yet, it is a defense which our society grossly neglects.

Americans have literally gone to the well for 180 consecutive years and have drawn a full if not an overflowing bucket. We must do more than assume we can do it a 290th time. We need a renewed national commitment to farming.

In conclusion, I just have a personal note. I understand this is Mr. Black's final appearance before the Congress. Mr. Black is retiring from his position as executive vice president of the Council of Agricultural Science and Technology. Mr. Black has played a key role in his liaison capacity to the professional agricultural science community and the Congress and I know this has oftentimes been a most difficult job, but somebody had to do it and you did it well. No one could have done it as well as Charlie Black.

Gentlemen, I welcome you all to the panel. We are in busy times right now and a state of confusion, if I can say that, with the way we are progressing on the Senate floor trying to figure out the procedural knots, which we have seemed unable to do. We have been tied in knots for 2½ days in session now, so with only 3 or 4 days to go we hope something happens, but it does cause problems trying to bring groups together. I, myself, have to leave soon and there will be somebody here, but I have to go to another meeting.

We certainly welcome you all and I can think of no one we are looking forward to hearing more from than you gentlemen. With that, our first witness is Mr. Black. We are going to start from the left. Mr. Black is executive vice president of the Council for Agricultural Science and Technology.

STATEMENT OF CHARLES A. BLACK, EXECUTIVE VICE PRESIDENT, COUNCIL FOR AGRICULTURAL SCIENCE AND TECHNOLOGY

Mr. BLACK. Thank you, Senator Abdnor.

Our headquarters office is in Ames, IA, in the Memorial Union. We are a national organization of 25 food and agricultural science societies. The organization is controlled by these societies through their representatives on the board of directors and we are supported financially by the societies, several hundred sustaining members and several thousand individual members.

We produce scientific educational publications on current food and agricultural issues of national importance, by means of multidisciplinary task forces of scientists who are nominated by their respective scientific societies.

In addition, CAST publishes a magazine, "Science of Food and Agriculture," that is sent free of charge to heads of science departments in high school grades 9 through 12 nationwide.

Today we are here at your invitation to review a study called "Development of New Crops." This report was prepared at your request by a task force of 23 scientists chaired by Mr. Paul Knowles, who is professor emeritus of the University of California at Davis. Mr. Knowles' specialty is oil crops and much of his research through the years has been on the development of new oil crops, including safflower, sunflower, and rapeseed. Mr. Knowles will discuss the biological aspects of development of new crops.

The second member of the task force here this morning is Mr. Melvin Blase. Mr. Blase will discuss the economic and procedural aspects of developing new crops. Mr. Blase is professor of agricultural economics at the University of Missouri-Columbia. He has participated in new crop studies for the National Science Foundation, the National Academy of Sciences—National Research Council. He is also a part-time farmer and in that capacity has grown one of these new crops, amaranth, on his own farm. You can say he has his feet on the ground.

The third member of the task force here this morning is Mr. Ronald Sampson. He will discuss organizational aspects and industrial aspects of new crop development. He is a chemical engineer and is the associate director for product development, industrial chemicals division, of the Procter & Gamble Co. in Cincinnati. He has worked on shortenings, oils and other food products and has been involved in new crops research and development for several years.

In line with CAST's status as nonlobbying, educational organization, the task force report contains some alternatives, but no recommendations. We expect the three task force members this morning to review the report and indicate when they are departing from the report to give their personal views. They are speaking for themselves as scientists, not as representative of CAST. CAST does not have any policy on any of the matters that our task forces address. We expect them to give their opinions freely and candidly if they think they will be useful or if you ask for them.

We appreciate the opportunity to prepare the report and review it for you this morning. Mr. Knowles on my left will be first and then Mr. Blase and Mr. Sampson.

[The prepared statement of Mr. Black, together with an attachment, follows:]

Prepared Statement of Charles A. Black

I am Charles Black, Executive Vice President of CAST, the Council for Agricultural Science and Technology. Our headquarters office is in the Memorial Union, Ames, Iowa.

CAST is a national organization of 25 scientific societies in food and agriculture. It is controlled by these societies through their representatives on the board of directors. It derives its financial support from these societies, its several hundred sustaining members, and several thousand individual members.

CAST produces scientific educational publications on current food and agricultural issues of national importance, mostly by means of multidisciplinary task forces of scientists who are nominated by their respective scientific societies. In addition, it publishes an educational magazine, "Science of Food and Agriculture," that is sent free of charge to heads of science departments in high school grades 9 through 12 nationwide.

Today we are here at your invitation to review a study called "Development of New Crops: Needs, Procedures, Strategies, and Options." This report was prepared at your request by a task force of 23 scientists chaired by Dr. Paul Knowles, who is Professor Emeritus of the University of California at Davis. His special area is oil crops, and much of his research has been on development of new crops, including safflower, sunflower, and rapeseed. Dr. Knowles will discuss the biological aspects of the report that is before you. Dr. Melvin Blase will discuss the economic aspects. He is a professor of agricultural economics at the University of Missouri. He has participated in new-crops studies sponsored by both the National Science Foundation and the National Academy of Sciences, National Research Council. As a part-time farmer, he has actually grown one of the new crops, amaranth, which is not yet commercialized; so he has his feet on the ground. Dr.

Sampson will discuss the chemical and industrial aspects. He is a chemical engineer, the Associate Director for Product Development, Industrial Chemicals Division, of the Procter and Gamble Company in Cincinnati. He has worked on shortenings and oils and other food products and has been involved in new-crops research and development for several years.

In line with CAST's status as a nonlobbying, educational organization, the task force report contains some alternatives, but no recommendations. We expect the three task force members here this morning to review the report and to indicate when they are departing from the report to give their personal views. Nonetheless, they are speaking for themselves as scientists and not for CAST, and so we expect them to give their own opinions if you ask for them or if they think their opinions will be helpful.

We thank you for the opportunity to prepare the report and review it for you this morning. Dr. Knowles will be first, then Dr. Blase, and finally Dr. Sampson.

CAST

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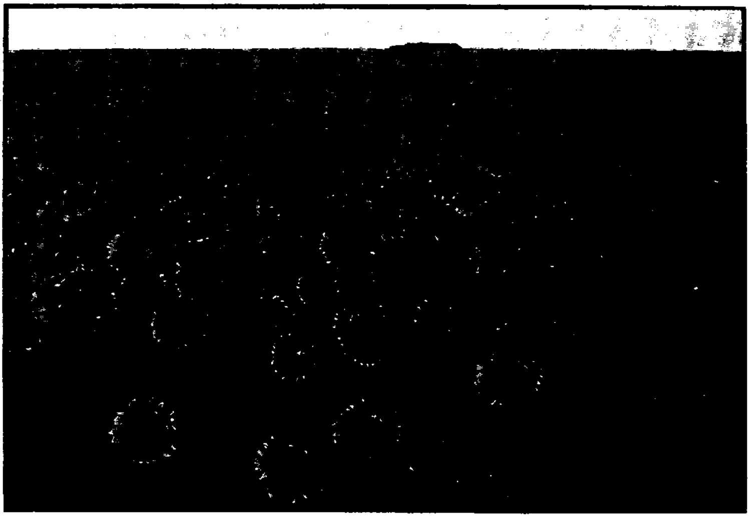
DEVELOPMENT OF NEW CROPS:
Needs, Procedures, Strategies, and Options



Council for Agricultural Science and Technology

Report No. 102
October 1984

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Publications in the *Report* Series are statements under joint authorship on the subject addressed. Proposals to establish a multidisciplinary task force of scientists to prepare a report are accepted from all sources. The proposals are normally acted upon by the Board of Directors at its semiannual meetings.

Each report bears the names of the persons who prepared it, and they are responsible for the content. Member society representatives serve on the CAST Board of Directors. The Board is responsible for the policies and procedures followed by the task force and the headquarters office in developing, processing, and disseminating the report, and the society representatives nominate qualified persons from their respective disciplines for participation in the task force. Aside from these involvements, the member societies have no responsibility for the content of any report.

Task force members serve as scientists and not as representatives of their employers. They receive no honoraria but are reimbursed upon request for travel expenses to meetings. Their time is contributed by their employers. Costs of preparing, publishing, and distributing the reports are borne by *CAST*.

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DEVELOPMENT OF NEW CROPS:
Needs, Procedures, Strategies, and Options

Council for Agricultural Science and Technology

Report No. 102

October 1984

Cover Picture

A field of sunflower. Now an established crop, sunflower is one of the success stories among new crops. Photograph courtesy of the U.S. Department of Agriculture.

Task Force Members

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Foreword

The immediate impetus for preparing this report on new-crop development was a request from Senator Roger W. Jepsen, who was interested in the possibility of a "National New Foods Foundation and Institute." Upon receipt of the letter from the Senator in October 1983, the CAST Board of Directors was asked to vote by mail ballot on whether to prepare the report because some months would elapse before the next meeting would be held. The Board voted in the affirmative, and the task force was constituted promptly on the basis of nominations of personnel made by official representatives of the member societies plus the task force chairman. The task force was charged with its responsibilities in November 1983.

As a result of unforeseen circumstances, the work did not proceed as rapidly as anticipated, and it was not until February 1984 that a tentative outline was sent to task force members for comment. On March 28 to 30 a meeting of 12 members of the task force was held in Kansas City to review the revised outline and prepare a first draft of the report. Some members of the task force had prepared their subject matter well before the meeting. The rough draft resulting from the meeting, with subsequent additions by some task force members, was reworked by the task force chairman, and the second draft was sent to the CAST headquarters office at the end of June 1984. The draft was typed, and the copy was edited by Ralston J. Graham with the aid of the headquarters staff. The rough edited copy was submitted to all task force members and the CAST Editorial Review Committee on July 6 for review, comments, corrections, and additions. A clean, retyped version was submitted a few days later.

The modifications received were taken into account in developing the next draft, from which the galley proof was prepared. The proof was sent to task force members and the CAST Executive Committee members for final review and approval on August 3, 1984.

On behalf of CAST, I thank members of the task force and all the others who gave of their time and talents to prepare this report as a contribution of the scientific community to public understanding. Thanks are extended also to the employers of task force members, who made the time of their employees available at no cost to CAST. And finally, thanks are extended to members of CAST. The unrestricted contributions they have made in support of the work of CAST have financed the preparation, publication, and distribution of the report.

The report is being distributed to certain members of Congress and the U.S. Department of Agriculture; to institutional members of CAST; and to an additional selected list of persons, including members of the news media who have asked to receive CAST publications. Individual members may receive a copy upon request.

Charles A. Black
Executive Vice President
Council for Agricultural
Science and Technology

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Summary

Numerous studies have identified the needs for, and potentials of, new-crops research and development.

Expanded research and development of new crops would provide a basis for:

• Enhancing economic development in terms of new products, such as industrial oils, medicines, pesticides, and fibers, as well as alternative sources for established crop products.
• Diversifying agricultural production, thus reducing surpluses of established crops and decreasing the vulnerability of U.S. agriculture to adverse or changing environments.
• Developing a strategic reserve of certain commodities necessary for national security.
• Improving the balance of payments by increasing exports and reducing imports.
• A more varied diet.
• Improving feeds for animals.

New crops or commodities may be developed by:

• Domesticating selected wild species. The process involves seven stages, which often overlap: germplasm collection, germplasm evaluation, chemical and utilization studies, agronomic and horticultural evaluation, breeding, production and processing scale-up, and commercialization. Ten or more years may be required.
• Adapting crops from other parts of the world to the environment of the United States. Some of the seven stages for domesticating wild species may be deleted or abbreviated.
• Making genetic changes in established crops such that a new commodity is produced. If the appropriate gene or genes are identified they can readily be transferred to a well established variety of the same crop.

The past record of new-crop development indicates that:

• Some new-crop development, as in the case of soybean, takes place slowly because changes in crop genetics, production technology, and markets must occur before the crop becomes profitable.
• Commodity (crop) champions have played a major role because of their enthusiasm and dedication.
• Development of many new crops must be attempted to provide for success because the probability of success is low for any one selected new crop, just as in new product research in industry.
• Premature attempts to commercialize a new crop often lead to frustration and financial loss to farmers.
• Early and sustained cooperation of public and private agencies and farmers increases the probability of success.
• New introductions may become persistent weeds.
• The strong program of species evaluation initiated some 25 years ago by the U.S. Department of Agriculture and universities provided a base for new-crops development. Through lack of support, that program has almost ceased.

To judge from past experience, new-crop developmental programs must provide:

• Recognition of an actual or potential market, which includes disposal of by-products.
• A basis for decision-making on the suitability of the crop for adoption at the farm level, with due regard for the area of adaptation, the susceptibility to pests, the availability of land, the need for specialized equipment, the production management skills required, and the productivity of competing crops.
• The necessary time for crop evaluation and development.
• A steady, sustainable level of support.
• Multidisciplinary efforts.
• Effective collaboration of relevant public and private interests.
• A process of evaluation, such as the production-marketing (including processing)-consumption system. Under the system mentioned, 40 items are identified as critical to success. A deficiency in any one may lead to failure of the new crop.

Several options, including the following, are available to carry out an expanded national program of new-crop evaluation and development:

• Increase support for existing state and private programs.
• Expand U.S. Department of Agriculture programs in terms of personnel involved, yearly funding, and duration of funding.
• Establish a New-Crops Coordinating Council by the federal government as an independent joint government-industry entity composed of representatives from research organizations, agricultural producers, processing and marketing industries, and consumers. It would serve as a clearing house for information regarding crop resources and uses, production and processing methods, market demands, and product quality and costs. With respect to new crops and their products it would maintain directories of individuals and organizations, sponsor workshops and conferences, encourage research and development of promising new crops, assist researchers in finding funding, and identify potential enterprises for entrepreneurs.
• Establish a National New-Crops Institute as an independent entity by the federal government, with the same functions as the New-Crops Coordinating Coun-

cil, but with the additional functions of funding and/or conducting in-house research, training technicians, and providing assistance to entrepreneurs in implementing promising new-crop developmental programs. The Institute hopefully would be funded in part by donations from industry. Federal funding could be based upon gross farm income, the cost of controlling surpluses of field crops, or some other index, with the amount allocated in any one year to be spent over a period of, say, 10 years, thus providing relatively stable long-term support.

• Provide development incentives to industry such that production and utilization would be in balance at acceptable prices. Financial incentives through loans and reduced taxes might cease at the end of the critical developmental stage or at some other appropriate time.

Introduction

Human history provides many examples of incorporation of new crops into established agricultural systems. For example, after the Europeans discovered the New World, corn, tomato, tobacco, sunflower, bean, cucurbits, and peppers became important crops on other continents, and farmers in the New World adopted wheat, oat, barley, rice, sugarcane, and many other crops from the Old World.

The process of adopting new crops continues to the present. The most important example in the United States is soybean (Appendix A). Essentially unknown to U.S. farmers prior to 1900, it ranked third after wheat and corn in acres harvested in 1980-1982 and second after corn in value of production in the same years (U.S. Department of Agriculture, 1983). Some of the other relatively new crops of increasing importance are sunflower (Appendix B), safflower, crownvetch, amaranth, paddy wild rice, annual canarygrass, yellow mustard, white lupine, pecan, pistachio, kiwi, and avocado.

The future will record other examples of new crops that have become successful in the economy of both the United States and other countries. To facilitate their development the National Science Foundation has sponsored two detailed studies of new crops. The Phase I report (Theisen et al., 1978) ranked potential new food, fiber, and industrial crops in order of their importance and described factors involved in their development. The Phase II report (Knox and Theisen, 1981) provided a detailed descriptive model of a production-marketing-consumption system for both established crops and the most promising potential new crops (crambe, guayule, grain amaranth, jojoba, kenaf, and pigeon pea) identified in Phase I. The Office of Technology Assessment, U.S. Congress (1983), published an excellent report on the potentials for extracting protein, medicines, and other useful chemicals from plants. Other reports examined by the task force include those by Lewis (1957), Task Group on New and Special Crops (1957), Knowles (1960), Joint Task Force of the Southern Region (1975), Pryde et al. (1981), Haun (1984), and Princen and Rothfus (1984).

Historically, when agriculturists perceived that a native plant species was useful, they sometimes domesticated the species by reproducing it and selecting the progeny, knowingly or unknowingly, for desired characteristics. Crops thus were developed and improved over periods of many centuries. Native plants may be domesticated and existing crops improved in a more directed and purposeful way in much less time by modern research and development techniques. This report will review crop development with examples from the past, emphasis on the present, and alternatives for the future. It will identify reasons for greater interest in and support of new-crops research and development. Then it will outline the stages in new-crop development. It will identify strategies for new-crop development and will conclude with a description of means for carrying out the strategies. Appendixes will describe the development of selected new crops, some well established, others not. The appendixes illustrate a range of crops in terms of development status and bring out some of the lessons learned in the development process.

Why a Need for New Crops?

Crop plants are the nation's most important annually renewable source of wealth. Fewer than 1% of the species of seed-bearing plants have been utilized commercially, and fewer than 3% have been evaluated in the United States. Nonetheless, the success achieved from new-crops research within the 20th Century is impressive, as witness the examples of soybean (Appendix A), sunflower (Appendix B), and safflower. Similar successes are likely to result from sustained research on other species, many of which are not yet domesticated. The benefits of research on new crops are discussed in this section.

Potential Contribution to Economic Development

In a classic book published in German many years ago, Joseph Schumpeter recognized new products and more efficient production of existing products as two of the sources of economic development (Schumpeter, 1961, is a translated version in English). Both sources have contributed markedly to rising affluence.

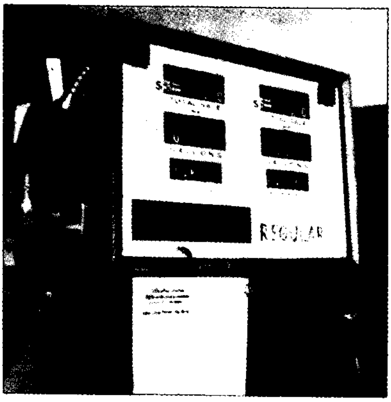
We are all better off as a result of new products. For example, computers, television, and most plastics are of post World War II vintage. New crops and new products, such as avocado, safflower, kiwi, margarine, and meat analogs have added to the diversity of our diets.

As diets become more sophisticated, more resources are required. New crops that contribute to more diversified diets as well as to industrial products thus result in increased economic activity.

New economic activity has resulted also from the improvement of some crops to the point that they have become essentially "new crops" on the American scene. Improved grain sorghum now is competitive with corn and soybean in some Midwest rainfed areas. It is the basis for a cattle feeding industry in the Great Plains. Sunflower has improved the well-being of some farm families in the Dakotas, Minnesota, and Texas. These developments are in accord with Schumpeter's earlier thinking.

The substantial increase in soybean production and domestic utilization during the past three decades provides lessons in the complexity of the economic consequences that may follow the introduction of a new crop. Margarine is a lower cost table fat than butter, and the substitution of margarine based on soybean oil for butter has reduced food costs and adversely affected the dairy industry. Substitution of soybean oil and other vegetable oils for lard in food fabrication (especially bakery goods) has reduced the cost of the foods, has adversely affected the pork industry, and has been responsible in part for the production of market hogs with a much lower lard content than previously. The availability of soybean meal as a protein source for animals has made a key contribution to the increase in poultry production and the substitution of poultry meat for higher priced pork and beef in human diets. Such adjustments are typical of the economic development process.

Development of new crops can occur slowly in an accidental fashion or more rapidly as a result of purposeful effort, which may be coordinated to different degrees. Perhaps the prime example of a coordinated effort in new-crop development that paid high dividends is the development of oilseed rape in Canada. Canada is now the world leader in export of oil from this crop.



Use of corn to produce alcohol for gasohol reduces the surplus of this crop. New crops, including Jerusalem artichoke, high sugar sorghum, and cattails are being investigated as energy sources. Photograph courtesy of Charles A. Black, CAST.

Reduction in Cost of Surplus Production

New crops compete with established crops for land and thus may reduce the total production of established crops. Therefore, if some land could be shifted from the production of crops now in surplus to those being imported, the costs of surplus disposal could be reduced at the same time as the balance of trade could be improved.

Additionally, new crops that are used for birdfeed, condiments, soil cover, and other purposes that are not competitive with those of the major crops help to reduce surpluses of the major crops and the costs to taxpayers of dealing with these surpluses. Successful new crops in this group include annual canarygrass, crownvetch, yellow mustard, oriental mustard, coriander, flatpea, and birdfeed sunflower.

The increasing costs of petroleum have resulted in efforts to develop alternative sources of energy. Because of the tremendous amounts of energy required in the U.S. economy, a crop source of energy that is economically competitive with petroleum, currently the principal energy source, could have a major effect in reducing surpluses of existing crops. Existing crops are used to some extent as energy sources (e.g., corn for alcohol to produce gasohol), with help from government subsidies. New crops, including Jerusalem artichoke, high sugar sorghum, and cattails, are being investigated. Moreover, oils from crops may be used to substitute for petroleum for purposes other than providing energy. For example, they may be useful in lubricants. Robinson and Nelson (1975) pointed out that oil from camelina (a potential new crop), as well as oils from sunflower, soybean, and flax, could be used as carriers and adjuvants for pesticides.

Relative to domestic market requirements, the United States has substantial excess capacity to produce food

Jojoba is a desert plant that is tolerant of both drought and salinity. The plant occurs naturally on about 90,000 acres of desert in Arizona, California, and Mexico. On the left is a wild jojoba plant in California. Note the spreading habit. On the right is a commercial field. For commercial production in desert areas, some irrigation is needed. To provide for mechanized harvesting, jojoba is planted in rows, and the plants are pruned to produce upright growth. Jojoba produces a useful wax. Photographs courtesy of D. M. Yermanos, University of California at Riverside.

and kindred products. The magnitude of the excess is difficult to quantify, but excesses of most if not all crops have been produced. Nearly 40% of the output harvested in 1979-1981 was exported. Moreover, stocks accumulated during this period required a PIK (Payment in Kind) program in 1983 to reduce stocks to manageable levels for the government. Thus, perhaps as much as 50% of the crop production in the United States is dependent upon export markets, which tend to be less stable than the U.S. market.

The cropland of the United States is more than adequate to provide the needs for food and kindred products for the U.S. domestic population into the indefinite future. The nation has added 80 million people since 1950 with no apparent pressures on the food supply.

Reduction in Vulnerability of American Agriculture

Water Supplies

Water is becoming increasingly scarce, especially in the arid West. The use of good quality groundwater in the West almost tripled during the three decades from 1950 to 1980 (Office of Technology Assessment, U.S. Congress, 1983). Consumption of groundwater exceeds the rate of replenishment in many areas. In some, most of the cropland is irrigated with groundwater pumped from a depth of 200 feet or more. Pumping from such depths is costly, and for many crops irrigation costs are as much as 30% of total variable costs.

Particularly in some parts of the Southwest, rapidly growing urban areas demand an increasing proportion of an inadequate supply of water and are able to pay more for it than are agricultural users, even to the point of buying agricultural land just to acquire the water rights. The development of crop plants with low water requirements, tolerance to drought, or the capacity to complete their life cycles quickly when moisture is available has the potential for maintaining agriculture where water supplies are decreasing.

Many major crops, including corn, wheat, cotton, sorghum, soybean, and forages, can be produced successfully over wide geographic areas in the United States, but that is not true for all crops. Certain specialty crops, including citrus, avocado, and artichoke, can be grown only in limited climatic areas in which competition with urban needs for water tends to be most critical. Decreasing supplies of land and water for these crops could become a problem during the next century.

Salinity

Soils and irrigation waters contain salts that can be detrimental to crops. At present, salinity is a threat to about 25 million acres of irrigated land in the West, and about a fourth of this area is already experiencing some limitation in production. In humid regions, salinity is of limited concern because rain water is almost free of dissolved salts, and excess salts are flushed continually from the soil. Where supplemental irrigation is practiced in semiarid to subhumid areas, however, salinity problems may increase. The combined effects of salt accumulation and groundwater depletion lead many experts to believe that present irrigation agriculture cannot be sustained (Office of Technology Assessment, U.S. Congress, 1983).

Crops differ in their tolerance to salinity. A beginning already has been made in developing crop varieties that have increased tolerance to salinity, and more progress can be anticipated as new plant types are developed from more divergent genetic materials.

Air Pollution

Unfavorable effects of air pollution on plants in the vicinity of certain smelters and other industrial sources of large amounts of gaseous pollutants have long been known. More widespread effects are evident in a few

Crownvetch is a new crop that was not thought to be of economic value until 30 years ago. It is a perennial legume that now is used extensively on steep roadside banks to control erosion and weeds. Much crownvetch is seen along highways from Minnesota and Iowa eastward to the Atlantic Ocean. The upper picture shows a bank of crownvetch in bloom in Iowa. Crownvetch is useful also for reseeding erosive, abandoned mined lands for cattle pasture as well as for protecting sloping cropland against erosion when used as a permanent ground cover in production of row crops, such as corn, by the no-till method. The lower picture shows a field of corn maturing in a solid stand of crownvetch in Pennsylvania. For this use, the crownvetch is allowed to grow in the fall and spring only. It must be controlled with an appropriate herbicide before the corn is planted in the spring to permit the corn to grow. The soil is protected continuously, and erosion is almost nil. Upper picture courtesy of Charles A. Black, CAST; lower picture courtesy of Nathan L. Hartwig, Pennsylvania State University.

areas and are suspected in others. Losses amounting to more than $200 million annually have been estimated on the basis of inadequate information. For the most part these estimates have been based on easy-to-assess direct losses, e.g., leaf injury to potato vines that reduces yields, and leaf injury to lettuce and spinach that increases both waste and processing costs. Indirect costs may be harder to assess. Pollutants may predispose crops to plant disease and insect damage, thus increasing pest control costs. At very high pollutant levels, a producer may no longer be able to grow a given crop and may be forced to grow a less profitable substitute. Thus, a growing need exists to develop more tolerant crops and/or new crops for production in the most adversely affected areas. Air pollution from open-field burning of crop residues in some regions could be reduced if suitable alternative crops were available.

Soil Erosion

In spite of overproduction of several farm crops, cropland harvested in the United States increased from 336 to 350 million acres (4.2% increase) from 1950 to 1982 (U.S. Department of Agriculture, 1984b). In the Corn Belt, Lake States, and Delta States, the cropland harvested increased from 128 to 145 million acres. This increased cropping and the associated increase in the proportion of intertilled crops have been conducive to an increase in loss of soil from wind and water erosion, estimated to exceed a total of 5 tons of soil per acre per year on 241 million acres or about two-thirds of the U.S. cropland acreage in 1977 (Beatty et al., 1982). During that 32-year period, soybean acreage increased 5.4 times to 17.7% of the U.S. cropland area. Soils are more susceptible to erosion when planted to soybean than to corn and very much more susceptible than when planted to perennial forage crops or pasture.

Although the susceptibility of sloping soybean fields to soil erosion is well known, this is not characteristic of all new crops. Crownvetch, for example, is highly valued as a preventer of soil erosion. Until 30 years ago, crownvetch was a curiosity not thought to be of economic value. Today, motorists from Minnesota and Iowa eastward to the Atlantic Ocean see crownvetch growing on steep roadsides and controlling erosion very effectively. Crownvetch is a permanent soil cover that controls weeds, does not require mowing, and is a beautiful roadside plant. It is used also to reseed erosive, abandoned mined lands for cattle pasture as well as to protect sloping cropland against erosion when used as a permanent ground cover in production of row crops, such as corn, by the no-till method. Other perennial new crops, including bamboo, jojoba, and sanseveria, are compatible with soil conservation objectives. The crop architecture, rooting habit, and residue remaining after harvest are some of the features to be considered in selecting new crops if they are to control soil erosion.

Pests

Diversification of crops provides some protection against pests. Pests of one crop often do not trouble another. Moreover, the increase in populations of pests following continued production of a single crop frequently can be prevented by rotating this crop with others. For example, including sunflower in the cropping system of the Northern Great Plains, where wheat is the primary crop, permits control of grass weeds by application of grass-toxic herbicides to the sunflower, and control of broad-leaved weeds by use of herbicides toxic to such weeds on the wheat, which is a member of the grass family. The choice of crops and their sequence is one aspect of integrated pest management.

Reduction in the Economic Vulnerability of American Farmers

U.S. agriculture is dominated by a few crops that have an inelastic demand with respect to price. For each of these crops, the percentage decrease in price for all of the crop exceeds the percentage increase in total production. Hence, gross farm income for the crop declines. Today, with the capability to produce quantities of the major crops well in excess of domestic needs and with an export market inadequate to absorb the excess at acceptable prices, crop prices and farm income are low.

The introduction of new crops that do not compete with present crops for the same market or are selectively adapted to certain regions or conditions within regions could reduce the economic vulnerability of many farmers. By producing a wider variety of crops, farmers could reduce the risk of low prices due to over-production of a few crops. Further, new crops would spread some of the risks of pest damage and unfavorable weather. Although these sources of risk cannot be eliminated, they can be reduced as farmers increase the variety of crops on their farms.

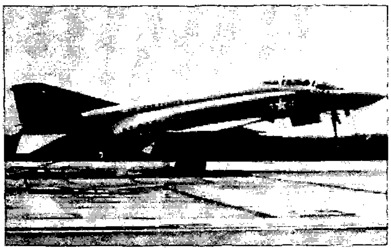
Provision of a Strategic Reserve and Stabilized Supply of Critical Crops

New Crops As a Strategic and Commercial Hedge

Development of appropriate new crops could serve the strategic interests of the country by providing alternative sources for imported raw materials that are not now produced domestically. Public law requires that stockpiles of these materials be established and maintained to meet national defense needs in case of war.

Despite the mandate of law, stockpile objectives have not always been met. For example, in 1980 the strategic stockpile of natural rubber contained about 100,000 metric tons, an amount substantially below the national stock-piling requirement of 800,000 metric tons specified by the Federal Emergency Management Agency (Office of Technology Assessment, U.S. Congress,

Rubber produced from guayule, a perennial shrub native to desert areas of north central Mexico and southwestern Texas. Rubber from guayule has properties similar to those of imported natural rubber. Photograph courtesy of the U.S. Department of Agriculture.



Guayule rubber tires pass a tire-scorch test on a military airplane making a simulated carrier landing at 145 miles per hour at the Patuxent River Naval Air Test Center in Maryland. Photograph courtesy of the Agricultural Research Service, U.S. Department of Agriculture.

1983). Because of the extreme sensitivity of the natural rubber market to U.S. demand, attempts to increase the stockpile resulted in dramatic price increases. Although synthetic rubbers have alleviated the domestic demand for the natural product, synthetic products do not duplicate fully the physical properties of natural rubber or completely eliminate the need for it.

Fortunately, a prospective new crop source of natural rubber, guayule, has been identified and exhaustively evaluated (Campos-Lopez and Alemany, 1980) (Appendix H). Although it is not currently economically competitive with imported natural rubber, it could be cost-competitive by the late 1980s (Office of Technology Assessment, U.S. Congress, 1983). Even today, guayule represents a potential strategic hedge against a future emergency in which the supply of natural rubber to the United States would be disrupted. Russian dandelion is another potential source of natural rubber. High-rubber lines were developed by USDA-Minnesota agronomic research during World War II, but the work was discontinued when imported natural rubber again became available.

On the basis of dollar values, about one-third of agricultural imports is classed as "complementary" products (Table 1). In addition to the critical materials, these complementary imports include significant quantities of other products that are important to U.S. industry and commerce but currently do not have an established and economically competitive domestic supply option available. These materials include a variety of waxes, resins, vegetable oils, and gums. A specific example is the lauric oils. These oils contain fatty acids of medium chain length[1] that are different from those in the vegetable oils produced domestically. They have unique properties and are needed particularly for the production of soaps, detergents, and certain other chemicals. In 1981, 540,000 metric tons of these oils were imported in the form of coconut and palm kernel oils (U.S. Department of Agriculture, Economic Research Service, 1982). In a previous world-wide screening program conducted by the U.S. Department of Agriculture, a candidate for a possible domestic crop source of these oils was identified. This potential new crop, cuphea, has been the subject of investigation in both the United States and Germany for several years (Thompson, 1984).

Benefits of a Stable Supply

In the absence of a national emergency or a supply crisis for a specific imported commodity, a new domestic crop source would need to be economically competitive with the imported source to be successfully commercialized. Successful commercial U.S. production of a new crop that would substitute for a previously imported crop would of course decrease the imports from the foreign sources. If the United States formed a significant part of the market, the capability of some countries to obtain funds to purchase products from the United States and other countries would be impaired. On the other hand, production of the crop in the United States would stabilize the supply for this country, and to some degree it would stabilize the world supply. Stabilization of the world supply conceivably could encourage increased use of the crop and reduce the permanent market losses to the original foreign suppliers that inevitably occur in times of erratic supply and pricing of annual crops.

The primary beneficiary of such supply stabilization would be the U.S. consumer, who would realize lower net costs for products made from the raw materials available from both domestic and foreign sources. It is noteworthy that today about two-thirds of the dollar value of U.S. agricultural imports is comprised of materials that supplement and compete with domestically produced goods (Table 1)—much to the benefit of the U.S. consumer.

Improvement in Balance of Payments

Although the United States is a net exporter of agricultural and kindred products, the nation ran a consistent total trade deficit from 1976 through 1983. The trade deficit increased from $2.4 billion in 1976 to $51.6 billion in 1983. Unofficial data and projections indicate that the deficit could exceed $100 billion during 1984. By providing substitutes for crops now imported as well as new products salable in foreign markets, new crops offer some potential for decreasing the deficit.

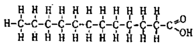
A decline in agricultural exports from a high of $43.8 billion in 1981 to $34.8 billion in 1983 contributed to the growing imbalance of U.S. international trade. The agricultural trade surplus decreased from $26.6 billion in 1981 to $18.4 billion in 1983. Agricultural imports decreased slightly from $17.2 billion to $15.5 billion during the recession year of 1982 but rebounded to $16.4 billion in 1983.

Table 1 shows the relative importance of food and kindred products imported into the United States in 1983. Coffee, cocoa, and bananas are the more important complementary foods imported. Beef and veal, sugar, vegetables, and wine are the most important competitive foods imported. Imported fish are utilized largely in feed and fertilizer manufacturing.

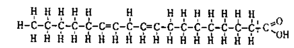
As mentioned previously, guayule is an alternative source of natural rubber (Appendix H), and jojoba is an alternative source of imported oils and waxes (Appendix E). Imports of natural rubber materials in 1981 amounted to $767 million (U.S. Department of Agriculture, 1982).

In addition, the United States annually imports about

[1] Lauric acid itself is a saturated acid with a chain length of 11 carbon atoms (each attached also to two or three hydrogen atoms) connected to a single carboxyl or acid group:



Linoleic acid, a common constituent of domestic vegetable oils, is an unsaturated fatty acid with a chain of 17 carbon atoms connected to a single carboxyl or acid group:



This fatty acid, which is essential in animal nutrition, has double bonds between adjacent carbon atoms at two locations in the molecular chain. Note that one less hydrogen atom is connected to each of the double-bonded carbons than to the other carbons within the chain. The double bonds are responsible for the designation of linoleic acid as an unsaturated acid (often called a polyunsaturated acid because it has more than one double bond).

Table 1. U.S. Agricultural Imports for 1983 (U.S. Department of Agriculture, 1984a)

Product	Unit[a]	Quantity	Value
			Thousands of dollars
Total[b]			16,620,642
Complementary			5,527,979
Competitive			11,092,663
Coffee	MT	1,021,644	2,771,052
Beef and veal	MT	641,819	1,362,913
Vegetables and preparations	MT	1,779,729	1,164,511
Sugar (cane and beet)	MT	2,644,389	1,025,569
Wine	HL	4,870,753	844,079
Cocoa	MT	447,193	840,633
Tobacco	MT	239,175	743,526
Rubber	MT	683,706	654,599
Pork	MT	251,776	610,645
Bananas	MT	2,545,995	660,303
Fruits and preparations	MT	954,692	558,785
Malt beverages	HL	7,408,700	515,235
Cheese	MT	129,827	383,296
Cattle	NO	920,807	312,642
Nuts and preparations	MT	137,132	250,405
Nursery and flowers			236,844
Coconut oil	MT	449,389	223,078
Casein	MT	72,358	188,190
Spices	MT	80,681	174,925
Crude drugs	MT	42,597	170,419
Horses and mules	NO	16,064	160,049
Wool	MT	46,461	150,010
Tea	MT	77,451	131,552
Furskins			126,259
Essential oils	MT	10,643	97,981
Seeds	MT	83,740	89,951
Palm oil	MT	149,110	60,756
Swine	NO	447,465	56,753
Olive oil	MT	33,113	47,531
Castor oil	MT	33,676	31,279
Mutton and lamb	MT	8,752	23,526
Poultry meat	MT	1,594	6,316
Fish	MT	13,197,897	3,607,971
Fertilizer	MT	13,556,662	1,404,896
Agricultural chemicals	MT	40,354	144,512
Farm machinery			1,358,764
(Other residual)			2,007,030

[a]MT = metric tons; HL = hundreds of liters (1 liter = 1.0567 quarts); NO = number.
[b]Does not include fish, fertilizer, agricultural chemicals, and farm machinery.

7 million tons of newsprint with an estimated value of $3.5 billion. Although newsprint is not classified as an agricultural product, the crop known as kenaf is an alternative source (Appendix G).

Improved Productivity

American agriculture has an excellent record of improved productivity in major crops, most of it achieved through the use of improved varieties and production practices. Needed, however, are crop choices that will permit better use of land that lies idle for portions of the year. With more crop choices it may be possible to increase the opportunities for double-cropping or substitutes for summer fallow. Investments must be made to develop the profit potential of new crops before they can become economically viable choices.

Planting soybean in barley stubble (left) directly following the combining of the barley (right) in Maryland. Double cropping, the use of two crops each year instead of one, is increasing in importance as a means of augmenting farm income. Successful double-cropping requires plant breeders to develop crop varieties that are adapted to this practice. Photograph courtesy of the U.S. Department of Agriculture.

Double-cropping, the use of two crops each year instead of one, is increasing in importance because it increases farm income. For example, soybean has been used in the Southeast as a summer crop following a winter grain crop, and would be used in a similar way in California if better adapted and mite-resistant varieties were available. In some areas of the irrigated Southwest, attempts are being made to combine cotton as a summer crop with grain as a winter crop. Vegetables and agronomic crops are commonly double- and triple-cropped in the Southeast. The use of double-cropping will increase as more choices of crops become available. Successful double-cropping will require breeders to develop varieties of crops that are adapted to the practice.

One example of successful crop substitution for summerfallow is the sunflower in southcentral Spain. There, some 20 years ago, the prevailing cropping system was wheat-summerfallow. In much of that area the cropping system now is a wheat-sunflower rotation, which has added almost 2.5 million acres of sunflower production to Spain's agricultural economy. The opportunity for U.S. agriculture to explore the potential of summerfallow substitutes would be enhanced with more crop options.

In areas of southern Pakistan where rice is the major crop, many fields lie fallow during the winter between rice crops. Some farmers have successfully grown

A field of sunflower in Spain. Replacement of the traditional wheat-summerfallow cropping system by a wheat-sunflower rotation in the last 2 decades has led to the production of some 1.5 million acres of sunflower in south central Spain. The oil produced from the new crop reduces the country's deficit of vegetable oil. Photograph courtesy of Paul F. Knowles, University of California (retired), Blaine, Washington.

brown mustard by broadcasting seed in the standing rice as the water is being drained off. As the rice is harvested and removed from the field the mustard seed germinates, and the plants mature well before the next rice season begins. As better adapted varieties of both mustard and other crops are developed, and as production practices are improved, crops undoubtedly will replace the winterfallow. Again, a greater range of crop options in the United States would permit better use of land in winterfallow.

Availability of profitable new crops would allow farmers to make crop selection choices based on commodity prices. This could be expected to result in more profitable use of agricultural land. Focusing production on one or a few major crops may stifle farmers' ability to make such acreage adjustments in response to market demands, and occasionally it may prompt the removal of high quality land from production.

Useful New Products

Historically, plants have served us well as sources of medicines, insect control substances, food, fiber, animal feed, oils, and waxes and as the original source of many organic chemicals. Plants contain many complex chemical structures, such as proteins, complex carbohydrates, oils and waxes, and steroids, which either cannot be produced synthetically or cannot be produced on the scale required as easily and economically as they can be derived from plant sources.

Medicinal Plants

Despite the common perception that prescription and over-the-counter drugs are synthetic, about one fourth of all prescriptions contain one or more biologically active substances derived from higher plants. A major steroid raw material for "the pill" comes from a plant source. Under research now are antitumor drugs derived from plants. One has been tested against leukemia in both this country and China, with favorable preliminary results. Some of these plant-derived drugs may be synthesized eventually. Even if this occurs, the plant research will have contributed significantly to human health and well-being by providing the needed molecular model for biological activity. Moreover, the crop source may have furnished interim raw materials and/or products. In recent years, however, the effort to discover and develop new drugs from natural sources has been reduced.

Pesticides

Among the constituents of plants important to humans (and to plants in their defense against insects) are insect toxicants, attractants, repellants, antifeedants, growth inhibitors, and sterilants. Certain plant-derived insecticides, including nicotine, rotenoids, pyrethrum, and hellebore, have been used for centuries, but many additional plant substances with a variety of biological activities against insects have been discovered in recent years. Now being investigated are weed-control substances (herbicides) derived from plants.

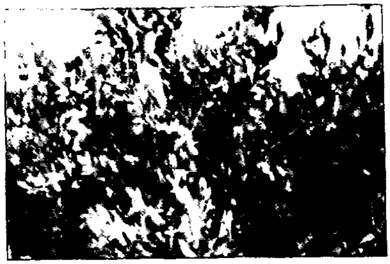
Some natural pest control agents from plants may offer advantages of more rapid biodegradability, lesser toxicity to humans and other higher animals, and greater specificity than the synthetic pesticides now employed. Any new and effective pest control agent reduces the hazard of potential loss of control associated with development of pest resistance to existing control agents.

Seven plants recently have been selected by U.S. Department of Agriculture scientists as especially promising crop sources of insect control agents. Most of their active principles are too complex chemically for commercial synthesis to be practical. Hence, the possibility exists that these plants could be developed profitably as new crops. The possibilities that abound for the isolation of needed and desired pest control agents from higher plants remain a challenge for future exploitation. Because the chemical industry can produce effective proprietary synthetic pesticides it has little economic incentive to invest in the development of new crops from which substances with pesticidal properties may be prepared. Hence, the developmental work must be done primarily by the public sector.

Oils and Waxes

By far the most extensive and largest use of plant oils and fats is for food. The principal food uses are in

Jojoba female flower [left] and fruit [right]. As the fruit ripens, the pods split. If not harvested at the proper time, the seeds fall to the ground. Jojoba usually produces 1 or 2 peanut-size seeds per pod. The seeds contain a high-quality, heat-tolerant wax. Photograph courtesy of D. M. Yermanos, University of California at Riverside.



A prolific female jojoba plant. Jojoba is a dioecious plant. That is, the male reproductive organs [producing pollen] and the female organs [producing seeds] occur on different plants. Male and female plants cannot be distinguished until they reach the stage of producing flowers and seeds, which requires about 4 years. Then most of the male plants are removed, leaving one male plant per 20 to 30 feet of row. Photograph courtesy of D. M. Yermanos, University of California at Riverside.

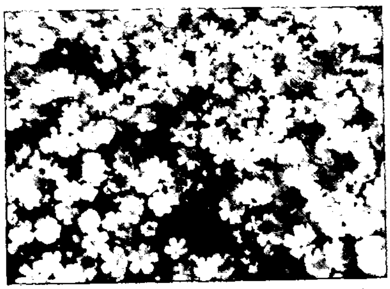
margarine, salad and cooking oils, and shortenings. The most important nonfood uses include soaps, fatty acids, animal feeds, and other industrial products.

Little need exists for new sources of edible oils except possibly for replacing imports, such as coconut oil, and satisfying changing dietary desires for specific types of unsaturated or dietary oils. The market potential for new plant-derived oils and waxes for industrial and specialty uses is much greater. Occasionally shortage or disappearance of current raw materials (e.g., sperm whale oil) means that new sources are needed and sought to meet an established need. Continuing and rapid changes in marketplace needs suggest that new products may find a commercial niche. Finally, producing directly in a natural product certain complex chemical raw materials that are made currently from petroleum and other simpler starting materials by a series of sometimes costly chemical steps may offer economies in obtaining needed products. Many opportunities exist for fabricating lubricants, surfactants, plastics, cosmetics, elastomers and other polymers (e.g., adhesives, thickeners, flocculating agents, coatings), and other industrial products from new seed oils and their products.

Most seed oils are predominantly triglycerides, but a very small percentage of them contain other principal constituents, such as waxes (long-chain alcohols esterified with long-chain fatty acids), glycolipids, cyanolipids, acetoglycerides, polyglycerides, terpenoid esters, etc. Many uncultivated plant species have seeds that are high in oil, and many contain fatty acids having new, different, and reactive functional chemical groupings. In some instances the unusual fatty acids are present in herbaceous species that offer potential for development into economic crops.

Each novel fatty acid structure presents a new material that may introduce the potential for a set of reactions, properties, derivatives, and conversion products not hitherto readily available from seed oils in current economic plants. Herein lies an opportunity for new oilseed crops. Of the 200,000 or more species of seed-bearing plants, however, only a few have been evaluated chemically; consequently, many undiscovered and potentially useful molecular configurations in seed oils probably exist.

Examples of oilseed plants found through research to have potential as new crops are (1) cuphea (Appendix I), which has an oil like that of coconut oil; (2) crambe (Appendix D) and meadowfoam (Appendix F), which



A stand of meadowfoam in full bloom. Meadowfoam, a winter annual plant adapted to wet soils, shows promise as an oilseed crop in Oregon. Photograph courtesy of Gary D. Jolliff, Oregon State University.

contain oils that are useful cosmetic and lubricant ingredients, sources of wax, and sources of other new chemicals; (3) jojoba (Appendix E), a dryland shrub that produces beans containing an unusual valuable liquid wax similar to that of sperm whale oil; and (4) buffalo gourd (Appendix J), a dryland cucurbit that yields seeds containing an edible oil similar to corn oil, a seed meal high in protein, and a fleshy root high in starch.

Fiber

One large-scale use of plant materials has been for cordage and pulpmaking fibers. Fiber for preparing paper pulp is by far the larger market, and it has largely resisted the inroads of synthetic raw materials. Wood is the most widely used pulping raw material, and it is the standard of comparison for new fiber crops.

The principal reasons for seeking new crops for pulpmaking fiber are to find sources that are less costly and produce higher returns. In times of high per capita usage of paper and paperboard, tree farming and reforestation programs in some regions of the United States fall short of replacing the wood that goes into pulping operations. Some of the pulp and papermaking plants built in the 1940s and 1950s are having to go farther afield for raw materials; inexpensive, dependable, and readily accessible supplies of pulpwood are becoming more scarce. Pulpwood prices are expected to increase at higher than average inflation rates during the 1980s in the South, where fewer than half of the mills enjoy relatively good access to their wood supply (Taylor et al., 1982). Moreover, sawtimber brings a better return than does pulpwood. Growers who have trees suitable for either sawtimber or pulpwood (some pulpwood species have little if any market value as sawtimber) thus sell their trees as sawtimber whenever feasible, and this increases the price of pulpwood.

According to research by the U.S. Department of Agriculture's Northern Regional Research Center at Peoria, Illinois, the most promising new fiber crops are bamboo, sorghum, eucalyptus, crotalaria, and kenaf. Kenaf was considered a leading candidate because of its high yield potential and good fiber quality. Hence, most of the recent U.S. research on new fiber crops has been on kenaf. Its use as a "one year tree" has intrigued many government scientists, agriculturists, and private sector investigators (Appendix G). The regions most frequently referred to as appropriate for early exploitation of new fiber crops are the Southeast, South, and Southwest.

A portion of a kenaf stem with the bark peeled back. Note the fibers extending from the cut bark. Kenaf is a fast growing tropical or semitropical annual plant that can be used as a source of fiber for making paper. Photograph courtesy of the U.S. Department of Agriculture.

Horticultural Crop Needs

Horticultural crops supply a wide array of commodities, representing an aggregate wholesale value of more than $16 billion annually. These crops include landscape and ornamental plants, as well as the raw materials of the canning, freezing, dehydrating, and fresh market fruit and vegetable industries. Worldwide, fruits and vegetables represent one-third of the total value of all crops. Horticultural products are significant items in both U.S. exports and U.S. imports. The future potential for increased export of horticultural crops is very promising.

The demand for new types of trees, shrubs, flowers, bedding plants, groundcovers, lawngrasses, and vegetables suitable for growing in pots and other types of containers for servicing the needs and desires of more than 35 million homeowners is never ending. The fast-developing area of interiorscapes in business offices, shopping malls, and public buildings as well as in private homes results in a heavy demand for new and improved plants that are adapted to stressful indoor conditions involving low light intensity; extremes in relative humidity, temperature, watering, and nutrition; and reduced physical space and soil volume.

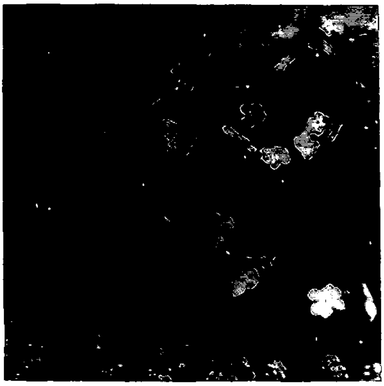
Within the past 10 to 15 years, a number of new horticultural crops have been established and have made significant economic impact. The first commercial planting of the kiwi fruit was made in California in 1962. Plantings now total about 4,000 acres. Farm gross returns are $6,000 to $8,000 per acre, translating into an industry value of approximately $25 million.

In recent years there has been increased use of oriental vegetables in the United States. These are grown as minor specialty crops on relatively few acres, chiefly in California, Hawaii, Florida, and New Jersey, but their value amounts to millions of dollars annually.

Another example is a new industry that has developed in southern Florida to produce special vegetables for both domestic consumption and export. This industry produces approximately 4,000 acres of tropical, whitefleshed sweet potatoes or "boniato" worth $4,800 to $8,400 per acre; approximately 3000 acres of the edible aroids (*Xanthosoma* spp.), variously called cocoyams, malanga, tannier, or yautia worth $3,000 per acre; 300 acres of cassava worth $3,000 per acre; and approximately 300 acres of the Cuban pumpkin or calabaza worth about $2,800 per acre. In total, the annual gross farm return on these new vegetables crops is approximately $30 to $34 million.

A similar potential for providing ethnic vegetables exists in many locations in the United States. In most instances these new crops could be grown and marketed locally. Unfortunately, local producers of traditional vegetables often are unaware of the market available to them for ethnic crops.

In 1970 a U.S. Department of Agriculture plant exploration team collected new germplasm of various species of the flowering plant impatiens in New Guinea



Germplasm of the flowering plant impatiens collected from New Guinea and Indonesia in 1970 has been developed into many new and more desirable varieties than those previously available in the United States. Once a rather dull and little-used ornamental, impatiens now has become very popular, and sales of the new varieties as bedding and pot plants are exceeded only by those of petunia. [The small flowers in the foreground are alyssum.] Photograph courtesy of Charles A. Black, CAST.

The grain-type amaranth pictured here produces an upright plant 4 to 8 feet tall with a bushy seed head somewhat similar to sorghum. The protein in the seed is rich in lysine, an amino acid essential in nutrition but found in relatively low levels in the protein from many other grains. There are also leafy types of amaranth that can be eaten in salads or cooked like spinach. Reprinted with permission from *The Furrow* (Volume 88, Issue 6, 1983), Deere and Company, Moline, Illinois.

and Indonesia, and distributed germplasm to plant breeders and geneticists in 1972. Until that time impatiens was a rather dull, little-used bedding plant. Basic genetic research and interspecific hybridization unleashed a tremendous array of new characteristics—flower color, flower types, new variegated foliage, plant types, and growth habits. Advanced breeding lines and varieties were developed and turned over to industry, and new varieties are continually coming into the trade. Currently the new impatiens are being sold as bedding and pot plants all over the country, and their sales are exceeded only by those of petunia.

New Food Demands

Consumers favor foods that are palatable, attractive, convenient to prepare, and cost competitive. During the past 30 years, considerations of nutritive value and potential contribution to obesity have become of increasing concern. On a per capita basis, the consumption of starchy foods, animal fats, dairy products, pork, mutton, lamb, and eggs has declined (Table 2). At the same time, consumption of beef, poultry, sweeteners, and vegetable fats has increased. Consumption of fresh fruits and vegetables appears to have declined somewhat, while that of processed fruits and vegetables fre-

Table 2. Changes in Per Capita Domestic Disappearance of Selected Foods in the United States in Various Years (U.S. Department of Agriculture, 1949-1961, 1969-1981)

Food	Per Capita Disappearance, Pounds of Retail Weight Equivalent Per Year in Indicated Time Periods				
	1949-1951	1959-1961	1969-1971	1979-1981	1982
			-Foods From Plant Sources*-		
Flour and cereal products	167.0	147.0	143.1	150.3	149.5
Potatoes, white and sweet	116.7	109.8	82.6	85.4	79.3
Sugars and sweeteners	109.3	108.5	121.5	133.8	133.9
Vegetables					
Fresh	170.1	147.9	140.2	147.1	150.9
Processed	43.7	50.5	60.8	60.2	56.3
Fruit					
Fresh	114.5	88.9	78.0	83.5	81.2
Processed	42.7	49.2	55.7	55.4	50.4
Fats and oils					
Animal	14.2	13.2	9.9	7.4	6.3
Vegetable	22.2	28.0	39.8	47.5	49.3
Beans, peas, nuts	17.7	16.7	16.4	15.2	17.5
Coffee, tea, cocoa	18.1	15.2	14.0	11.5	11.3
			-Foods From Animal Sources-		
Dairy products	406.7	384.7	336.7	307.5	302.1
Beef and veal	55.4	68.9	85.6	78.8	78.9
Pork	64.7	60.3	63.7	65.7	59.0
Mutton and lamb	3.4	4.4	2.9	1.4	1.5
All fish	13.3	13.5	15.5	17.0	16.4
Poultry meat	25.0	36.0	48.3	61.6	64.1
Eggs	48.4	42.9	39.4	34.6	33.4
			-All Foods-		
Total	1,506.3	1,439.3	1,397.7	1,406.8	1,387.4

*Except for animal fats.

quently has increased. Overall, the evidence from long-term trends suggests a declining per capita consumption of food, with considerable substitution among foods. Assuming, however, an increasing population, possibly to 300,000,000 by 2020, total food consumption will steadily increase.

These indications of consumer preferences and behavior presumably would apply to foods derived from new crops as well as to existing foods. Although the magnitude of demands for new foods is not clear, the examples of new food crops in the preceding section suggest that the market is by no means closed.

Needs in Animal Feeding

The plant resources that undergird animal production in the United States consist of feed grains, forage and silage crops, pasture and rangelands, and by-products of various processing industries. Six grain crops (wheat, rye, corn, oat, barley, sorghum) were grown on 196 million acres in the United States in 1982 (U.S. Department of Agriculture, 1983). Corn and wheat occupied 160 million acres or 82% of that acreage. In 1973 the comparable proportion was approximately 66% (Wedin et al., 1975), at which time 76% of the corn was fed to livestock.

Cereal grains are the foundation of swine and poultry feeds. These grains are fed directly and as by-products of the brewing and milling industries. Triticale (a relatively new cereal that resulted from crossing wheat and rye) grown for grain is increasing in importance in the Southeast as a substitute for corn in feed for swine. Triticale can be grown in a double-cropping system with sorghum, providing a more drought-tolerant combination than corn. The meals from soybean seed and cottonseed after extraction of the oil are the most important sources of animal feed from the oilseed crops.

In production of ruminant livestock (cattle, sheep, and goats) in the United States, pasture and range, hay, and silage are important sources of feed. The major contributions come from permanent pasture and rangeland, which play an important role in supporting the breeding herds of beef cattle and sheep. Silage and hay are most important for dairy cattle, beef cattle, and lambs. Overall, 80% of the total feed nutrients consumed by all ruminants are derived from forage (Wedin et al., 1975).

Higher yielding varieties of existing crops are sought for livestock and poultry in general. For ruminants, two new-crop possibilities appear to have the greatest potential: (1) Increasing the digestibility of the lignocellulose component of forages (Wedin et al., 1980). (2) Developing unconventional high-yielding alternative sources of nutrients. These may include certain types of trees (alder, aspen, poplar) as well as some aquatic plants now regarded as weeds.

Development of New Crops

The development of each new crop follows a unique path dependent upon the specific character and history of the crop and the uses it may find. Nonetheless, some useful generalizations may be made about the steps involved. Three kinds of development may be visualized: domesticating a wild species, adapting a domesticated species to a new environment, and modifying an established species to produce a new product.

Domesticating a Wild Species

The U.S. Department of Agriculture has designated seven stages in evaluating, developing, and commercializing a new crop. These stages are shown in Figure 1 and are discussed in this section. Although the stages are to some extent sequential, considerable overlapping exists.

Stage 1: Germplasm Collection

In this stage, germplasm (seed stock) is collected and classified. Emphasis is on collecting a broadly diversified array of samples. This stage can require as little as 2 years if germplasm is readily available and accessible. For species widely dispersed or located in geographically or politically inaccessible areas, however, collection could continue indefinitely.

Stage 2: Germplasm Evaluation

In this stage the seed is germinated, and initial cultivation is attempted. At this time the first indications of the potential use and value of the crop might be obtained from physical measurements and chemical analyses (e.g., oil and meal compositions for a prospective new oilseed). When the development of a new crop begins from a supply of only a few seeds, germplasm evaluation must be delayed until the seed stock can be multiplied through several generations of cultivation. Even on the most optimistic basis, the germplasm evaluation and seed increase stage requires several years and overlaps subsequent stages.

Identification and cataloging of chemical and other traits of plant introductions for easy access and utilization by plant breeders and others are very important. The deficiencies in the current system limit the usefulness of existing introductions.

Stage 3: Chemical and Utilization Studies

As soon as sufficient and representative quantities of the crop are available, significant effort must be focused on processing studies, comprehensive chemical analyses and physical property measurements, and actual product use. For a crop intended to be used wholly or in part for human food or animal feed, toxicological and nutritional qualities are evaluated. Processing studies to assess costs and technical feasibility are conducted in laboratories and pilot plants. When the crop is intended to be used as a raw material for a different finished product (such as kenaf for newsprint), the finished product needs to be produced and evaluated. Depending on the newness of the crop and its distinctiveness from existing crops or the raw materials it replaces, a

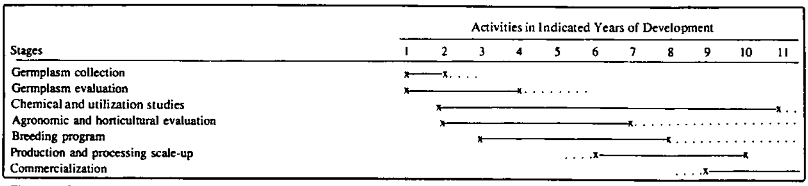
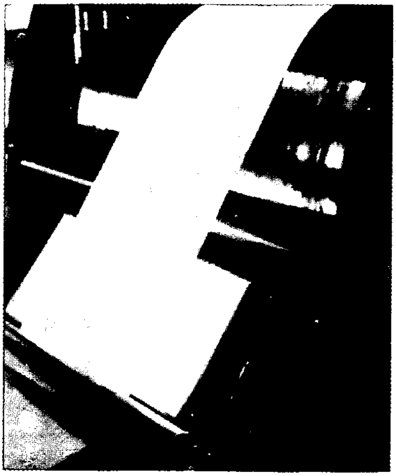


Figure 1. Optimistic timetable for domesticating a wild species.



Bond paper containing kenaf fibers being run on an experimental paper-making machine at the Northern Regional Research Center, U.S. Department of Agriculture, Peoria, Illinois. Photograph courtesy of the Peoria *Journal Star*.

considerable investment in research and development may be required.

Stage 4: Agronomic and Horticultural Evaluation

In this stage, initial evaluations are conducted to assess the possibility that the plant may become a successful new commercial crop. Emphasis must be placed upon the socioeconomic feasibility and the biophysical barriers, including the genetic modifications, special cultural practices, and harvesting methods that may be required. Tentative projections of economic and technical feasibility at this stage usually must be based upon reasonable assumptions about what might be accomplished in future work rather than being limited to what is proven at the time. The results must be carefully interpreted and properly qualified to avoid arousing unwarranted expectations among persons outside the immediate research group.

As time goes on and progress is made during this stage of development, the crop is grown on field plots at a variety of locations to evaluate its performance under a wide range of environments. Cultural practices, harvesting methods, and crop yields are assessed. On a most optimistic basis, this stage requires at least 5 years.

An irrigated field of crambe being grown for seed increase in New Mexico, where yields of 800 to 1800 pounds per acre have been obtained. Other areas where crambe has shown promise are Texas, the Pacific Northwest, the northern Great Plains, and the Corn Belt. Crambe can be planted and harvested with farm equipment used for small grain crops. Photograph courtesy of Koert J. Lessman, New Mexico State University.

Seed pods of crambe and objects formed from a tough new nylon obtained from erucic acid, the principal constituent of the oil extracted from the seed. Each pod contains one seed. Photograph courtesy of the Northern Regional Research Center, U.S. Department of Agriculture, Peoria, Illinois.

Cuphea is a potential source of oil similar to coconut and palm kernel oils. The stages in development of the seed proceed from the flower [upper left] through immature seeds [upper right, lower left] to mature seeds [lower right]. A major breeding objective is moving the seed from its current location outside the seed capsule [where the seed is exposed to serious losses from wind and rain] to a more protected location inside the capsule. Photograph courtesy of F. Hirsinger, Oregon State University.

Dr. H. M. Tysdal [left] and Dr. A. Estilai [right] in a guayule nursery near McFarland, California, examining a derivative from a cross of guayule [*Parthenium argentatum*] and a related species [*Parthenium stramonium*]. Dr. Tysdal is standing in a row of guayule, which is much less vigorous than the hybrid. The rubber content of the hybrid, however, is much lower than that of guayule. The problem is to raise the yield of rubber by combining the high yield of the hybrid plant with the high percentage of rubber in guayule. Photograph courtesy of Paul F. Knowles, University of California [retired], Blaine, Washington.

Stage 5: Breeding Program

The selective breeding used to develop varieties suitable for domestic cultivation can be carried out most efficiently if the traits of the existing introductions observed previously by others have been listed in an easily accessible data bank. In many respects this stage is the critical link between a wild or at least unadapted plant and a domesticated crop. Selective breeding is used to develop strains suitable for domestic cultivation. It is important at this stage to maintain a broad genetic base and not converge too quickly, with possible loss of desirable traits that might exist in the breeding stock. Mutation breeding and genetic manipulation may be used to introduce desired features into the crop and to remove undesirable features, thereby accelerating the pace of development. Breeding overlaps both agronomic or horticultural evaluation and the stages to follow. In practical terms breeding continues indefinitely — even after a new crop is successfully commercialized. As evidenced by the continuing breeding efforts on established crops, such as cotton, wheat, corn, and soybean, improvements in crop yields and other characteristics are always possible and desired. For example more than 120 U.S. scientists were involved in soybean breeding and genetics in 1981 (Judd, 1984).

Experimental application of a bioregulator to guayule plants to test its effect on the rubber content. Under favorable conditions, 4-year-old guayule plants may contain more than 20% rubber on a dry basis. Bioregulators could increase the yield to 30 to 35% and reduce the growing time by a year or two. Photograph courtesy of the U.S. Department of Agriculture.

Stage 6: Production and Processing Scale-Up

In this stage, the results of small-scale tests and projected economics are tested on a larger scale. The data, experience, and confidence will be generated to support expansion of the supply and development of the market for the crop. Many groups will become involved—farmers, seed producers, equipment suppliers, pesticide producers, governmental regulatory agencies, initial processors, final processors, marketers, and final users.

Stage 7: Commercialization

Commercialization cannot be successful without a market to absorb the product at a price that will yield a profit to producers. Although marketing comprises only three of the 40 factors in the production-marketing-consumption system decision matrix shown later in Table 3, the lack of an adequate market is the weak point that spells the downfall of many commercialization programs that are undertaken prematurely.

Summary Comments

Throughout the development of a new crop, many different disciplines or fields of expertise are involved, as well as many different types of organizations. In the initial steps, the principal roles are played by agronomists, botanists, chemists (and related utilization physical scientists), and horticulturists, usually within governmental and academic research institutions. As a crop progresses on the development path, it makes a gradual transition from an academic curiosity to a commercial reality. Accordingly, responsibility for its development gradually passes from academic and governmental institutions to private industry, including growers.

The chances for a plant to become a commercial success would seem to be enhanced by early involvement of and dialogue among all the parties needed for development from the initial researchers to the final processors or users. Such early involvement should increase the learning rate and help to guide the new crop along a path of rapid development.

Adapting a Domesticated Species to a New Environment

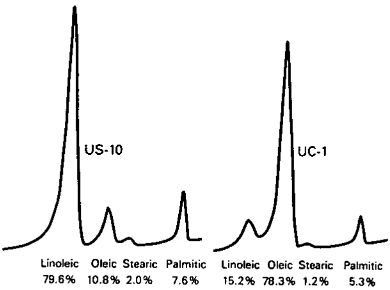
Stages of crop development for adapting an existing domesticated species to a new environment will be similar to those described for wild species, except that they will be telescoped into a shorter time period. If the crop product is well known, Stage 3 may be very short. If a large range of germplasm is readily available, stages 1 and 2 will be short.

An example is safflower in California. Initial evaluations of germplasm, most of it from the University of Nebraska, began in the winter of 1947-1948. By the 1950-1951 growing season, commercial production was underway. Stage 1, the collection of germplasm, most of it from the Old World, continued for several years thereafter.

Modifying an Established Species to Supply a New Product

The classic example of genetic modification of a crop product is the work in Canada with oilseed rape, which initially provided an oil high in erucic acid and a meal high in glucosinolates. As a result of genetic removal of the erucic acid, the new oil is now similar to soybean oil, and it is enabled to compete in a higher priced market. Canada is now the world's leading exporter of edible oil from rape. Moreover, as a result of a great genetic reduction in content of glucosinolates, the meal now is considered essentially equal to soybean meal in feed value. The "new crop" is referred to as "canola."

Originally safflower oil had a high content of linoleic acid, a polyunsaturated fatty acid. A mutant type developed in California had a high content of oleic acid, a monounsaturated fatty acid, thus chemically resembling olive oil. A single gene change provided a new product. Similarly sunflower varieties with oil high in oleic acid will become available in a few years. New-crop products resulting from changes in a few genes can be developed very quickly, once the genes are known and available.



Chromatograms illustrating the marked difference in composition of the fatty acid component of the oil from two varieties of safflower. The relative heights of the peaks reflect the relative proportions of the various acids. The standard variety [US-10] has a high proportion of polyunsaturated linoleic acid. The new variety [UC-1] has a high proportion of monounsaturated oleic acid. The oil that contains the high proportion of oleic acid is chemically similar to olive oil and has uses very different from those of the oil high in linoleic acid. Photograph courtesy of Paul F. Knowles, University of California [retired], Blaine, Washington.

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Strategies for Developing New Crops

In spite of the potential for new crops in U.S. agriculture, and in spite of past successes of new crops, such as soybean, safflower, and sunflower, new-crop development is not an easy task. Evidence of this is the past record, where disappointments have been common and successes often have required a great deal of time.

The Past Record

Haphazard New-Crop Establishment

The haphazard approach to the establishment of new crops has been slow, as illustrated by soybean (Appendix A) and sunflower (Appendix B). An efficient and orderly crop establishment process would reduce the time to payoff and would increase the return on investments of human and financial resources.

Commodity Champions

To an amazing degree, past experiences with new-crop establishment indicate the crucial role played by one or a small group of persistent individuals. In spite of great obstacles, they persisted in their enthusiasm for the potential new crop. Some of them were in a position to make key decisions themselves. More often, their personalities helped to attract decision-makers to the "cause" and to persuade them to make decisions favorable for the establishment of the new crop in question.

Low Probability of Success

Any single new-crop venture has only a low probability of success. New-crop research and development involves doing, or attempting to do, something that has not been done before. Each of a large number of factors must be favorable to make success possible, and failure will occur if only one of these factors is unfavorable. The development of new products in industry is a similar process. Development of many new products must be attempted to provide even a single success.

Premature Commercialization

Many instances may be cited in which a new crop has been promoted and grown commercially without adequate research and development. Usually it was the farmer who suffered because yields were low, required management skills were unknown, harvesting was difficult or costly, the price was lower than expected, or the promised market disappeared. It cannot be emphasized too strongly that research and development should precede commercial production of a new crop, and a market must be assured.

Effective Cooperation

Where public agencies involving both research and extension personnel, private agencies (including processors and product developers), and farmers work together harmoniously, the possibility of success has been greatly enhanced. Such was the case in the rapid development of safflower as a crop in California, where the University of California and the U.S. Department of Agriculture developed basic information on the crop and its production requirements, a commercial company guaranteed a market and a price for the seed, and the public and private agencies were in constant communication with farmers. Similar cooperation helped to establish sunflower as a significant new crop in the United States in a short time after a long period during which little developmental activity took place. The U.S. Department of Agriculture and universities provided the initial plant material leading to the growth of productive hybrids, seed companies followed rapidly with the development and provision of seed of improved varieties, companies interested in the oil and meal established a market and a price for the seed, and there was open and frequent communication of all persons and agencies involved.

Three pairs of large-seeded confectionery types of sunflower seeds (above) and three pairs of small-seeded oilseed types (below). In each pair, an intact seed is shown on the right, and a split seed exposing the kernel appears on the left. After a long period during which little development of sunflower took place, effective cooperation among the U.S. Department of Agriculture, universities, seed companies, and companies interested in the oil and meal led to a rapid increase of harvested area of sunflower from 600,000 acres in 1976 to 5,191,000 acres in 1979. The principal increase in acreage has been in the small-seeded oilseed types. Photograph courtesy of Paul F. Knowles, University of California (retired), Blaine, Washington.

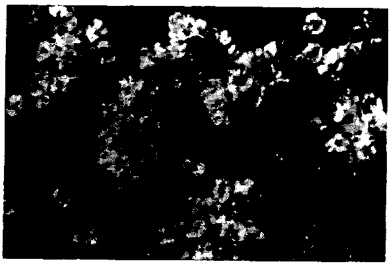
Kudzu, a prostrate Asiatic leguminous vine first introduced as an ornamental in 1876; was promoted also for its value for forage and soil erosion control. The plant soon became a pest. Above: Kudzu covering much of a gully more than 70 feet deep in Arkansas, illustrating the value of the crop for erosion control. Below: Kudzu covering objects in Athens, Georgia, illustrating the undesirable aspect of the crop. Upper photograph courtesy of the U.S. Department of Agriculture. Lower photograph courtesy of Jeff Clarke, University of Georgia.

Introduced Plants as Weeds

New crops that are very vigorous and competitive with existing species may become persistent weeds. For example, quackgrass, which was introduced to control soil erosion along roads, quickly demonstrated a remarkable ability to spread by both seed and creeping rhizomes and to persist as a weed in cropland. Kudzu, which was first introduced as an ornamental in 1876 and later promoted for its value for forage and control of soil erosion, became a serious pest of forested and parkland areas of warmer regions because its rapidly growing vines "smothered" other vegetation, including well estabished trees. Multiflora rose, a vigorous prickly bush, was introduced from Japan as a living fence, a highway safety barrier, and a soil conserver. Unfortunately, birds spread the seeds of multiflora rose, making it difficult to control in permanent pastures. Now it is classified as a noxious weed. Performance of a plant in a new environment must be evaluated carefully to assure that additional costs will not be required in the future to control it.

Past Evaluations

In 1957, the U.S. Department of Agriculture started a strong exploratory chemical screening and utilization research program on new crops as sources of industrial oils, fibers, gums, natural rubber, carbohydrates, proteins and amino acids, substances with antitumor and pesticidal activity, and chemical intermediates and feedstocks. The reasons were to alleviate the problems of overproduction of major agricultural commodities and to provide new opportunities for the chemical industry to use domestically produced raw materials in lieu of



A closeup view of a portion of a multiflora rose bush in bloom. The multiflora rose, a vigorous prickly bush, was introduced from Japan as a living fence, a highway safety barrier, and a soil conserver. Unfortunately, birds spread the seed, and the plant has proved difficult to control in permanent pastures. Photograph courtesy of the U.S. Department of Agriculture.

petroleum-based or imported commodities. Over a period of approximately 20 years, the U.S. Department of Agriculture's Northern Regional Research Center at Peoria, Illinois, screened about 8,000 plant species for their potential as future crops. The program has been very productive, with more than 75 new fatty acids and 40 other new chemicals discovered (Princen, 1977, 1983). The Center's current activity in this area, however, is at a low level.

The U.S. Department of Agriculture, in cooperation with plant scientists in universities and industry, further evaluated many of the more promising species in a preliminary screening program for botanical characteristics and potential for production as commercial field crops. Additional germplasm of some species was acquired and grown for seed increase, and selections of superior strains were made. Plant breeders and agronomists have done some additional work to upgrade the wild germplasm to useful crop materials and to develop appropriate cultural practices necessary for increasing yields and product quality. This effort has resulted in a series of prospective new crops that are in various stages of development.

Successful though the exploratory program has been in some respects, and despite considerable effort to develop usable varieties and suitable cultural and management practices, only one crop, kenaf, is approaching commercial status. Members of the task force that produced this report do not agree on the cause of the failure of the program to result in commercialization of one or more crops, but they have advanced the following as probable causes from their several perspectives: (1) The program was one-sided and did not lay sufficient emphasis upon supporting the broad range of research and development activities required to develop new crops. (2) The program was not carried far enough to develop fully the economic potential of the plants. Adequate provision was not made for the sustained long-term support (12 to 15 years) for the coordinated breeding and agronomic work required after screening had identified a potentially desirable crop species. (3) The group of potential crops tested did not include highly promising species. (4) The program was disabled by inadequate and erratic financial support, coupled with changes in priorities and personnel, loss of scientists trained in the area, lapse of needed data bases, loss of germplasm, and loss of the momentum and enthusiasm engendered by research programs with adequate and stable support.

The number of plant species evaluated in the total U.S. Department of Agriculture program is less than 3% of the total number of known species in the plant kingdom. It seems likely that some of the remaining 97% have desirable chemical constituents that would be of value if they were known and the species were developed as crops.

Effective New-Crop Development

Economic profitability is the most important factor. Profit incentives are the basis for most crop production decisions. If a crop is not profitable it will not be adopted; if highly profitable, it will be almost impossible to prevent the crop from being produced, as indicated by the experience with marijuana. The research and development lessons of the past provide a basis for success in the development of new crops from the technological standpoint. Annual rates of return to the public on expenditures for agricultural research are of the order of 50%. Lacking has been the political commitment to proceed.

Recognition of a Market

The probable market demand for products derived from a potential new crop must be evaluated before the crop is promoted for commercial production. A demonstrable need for a new crop product obviously will favor the development of the crop to commercial status. Examples are guayule (Appendix H), which produces natural rubber, a critical commodity in the United States, and cuphea (Appendix I), which produces an oil resembling coconut or palm oil. The needs of the market, however, are not always so obvious. When safflower types with monounsaturated oil (high in oleic acid) first became available, the vegetable oil industry saw no future for the oil. Later the market value was recognized. Now sunflower types are being developed with oil in which the fatty acid component is almost pure oleic acid. Soybean types with low linoleic acid content and a high content of oleic or stearic acid will be available soon.

Disposal of byproducts is an important consideration. For example, when sunflower seeds are processed for oil, the two byproducts are the meal and the hulls. The meal has a market because of its high protein percentage. The hulls, if ground, can be sold as an ingredient of the meal, but only by discounting the price of the meal. Recently built sunflower processing plants have solved the problem by burning the hulls to provide the energy needed for processing. The surplus energy is sold as electricity.

The Production Component

Early in the development of a new crop an evaluation needs to be made of its probable suitability for adoption by farmers, with due regard for the area of adaptation, the availability of land, the costs of production (with particular attention to needs for specialized equipment), the probable net returns to the farmer relative to those from competing crops, and the likelihood that the competitive position of the crop will improve with time in response to continuing efforts in research and development.

Coordination of production and marketing is very important. If markets are created before production can fulfill the demand, buyers may become disinterested, and the product's chance for success may be impaired. If production exceeds market demand, farmers will become disillusioned. If a market exists but well-established products already meet the demand, products from the new crop must have a lower price or superior quality to be successful in competition. Finally, consumer acceptance is a key factor in effective market demand; the product must be one the consumer will buy.

A Long Time Involved

Even under the most optimistic circumstances, new-crop development takes a long time. It cannot easily be hastened, but it can easily be delayed. Nonetheless, its progress can be monitored to assure that the expenditures are being made wisely. New-crops research must be sustained (with checkpoints along the way) for at least 10 and more likely 20 years. This time scale goes beyond that familiar to, and certainly comfortable for, most people in government and industry. It is almost incomprehensible to the general public. Those who successfully promote new crops will be recognized in historical perspective as wise, far-sighted individuals. In the short term, while results are limited, disillusionment must be avoided, and faith in eventual success must prevail.

Maintenance of a Steady, Sustainable Level of Support

Sudden major infusions of money at unsustainable spending levels cannot be used efficiently. Such funding may promote discomfort and undue impatience on the part of the sponsors, particularly in view of the long-term nature of new-crops research. Ideally, new-crops research and development programs are conducted in an orderly, noncrisis manner. This approach is most efficient in the long run.

Multidisciplinary Effort

New-crop development warrants attention from specialists in various disciplines, including plant taxonomy, chemistry, agronomy, horticulture, plant pathology, entomology, nematology, genetics, plant breeding, weed science, agricultural economics, agricultural engineering, product processing and development, and marketing. The amount of effort needed from an individual specialist will vary with time, and may be large or small. Flexibility of funding and staffing to accomplish the needed research and development on a timely basis thus is needed. This principle is important for both intra- and inter-agency projects. New-crops research efforts, however, are often inadequately funded and deficient in support from one or more disciplines.

Provision of a Data Bank

Before a desirable trait of a plant can be used in a breeding program it must be known. This requires systematic screening and cataloging of the information in an easily accessible data bank. The Economic Botany Laboratory of the U.S. Department of Agriculture has developed "data base files" on minor plant species in seven different categories: ecosystematics, mostly providing environmental adaptation of individual species; yield, mostly from experiment stations; climate of about 20,000 stations worldwide; nutritional value, in terms of concentrations of elements, vitamins, calories, and fiber; medicinal and poisonous properties; agroforestry, which includes the cultural requirements and uses of woody species; pests in the area where the species is grown; and intercropping possibilities. These files are of assistance in identifying species adapted to specific environments and in finding the available information on the uses, production, and adaptation of specific species. Such information is useful to new-crop development, particularly in the initial stages. In recent years, however, the funding for these files has declined, and the files are not up to date.

Effective Public and Private Collaboration

During the past two decades the level of sustained public support for agricultural research has steadily declined in real terms. Public funding has been moving in the direction of short-term grants, which generally are inappropriate for and unavailable to most new-crops research programs. With established crops some industry organizations have provided supplemental research funding on a continuing basis. Such support rarely has been forthcoming for new crops, at least in the initial stages of their development. Industries based on established crops may lack the incentive to support new crops that might reduce the production and increase the cost of established crops to the industries.

If new-crops research and development are to be fruitful, appropriate collaboration of public and private agencies is needed on at least the more promising new-crops programs to develop and demonstrate their profit potential. As a new crop advances into commercial production, the close cooperation of research and extension personnel (usually with public agencies) and industry representatives will do much to make farmer participation successful.

New-Crop Establishment: A Systems Process

Most major crops in the United States were established over a long period of time. Production, processing, marketing, and consumption gradually evolved together to accommodate the crops. Similar adjustments must occur with the purposeful development of new crops, but the time frame is so short that special means are needed to assure that the required evolution takes place in a short time. Studies of new-crop development have led to a conceptual production-marketing-consumption system (Knox and Theisen, 1981) to aid in assessing the probable success of a potential new crop. Components are given in Table 3, which identifies 40 items that require attention in new crop development. The neglect of or failure to implement only one of these items may lead to failure. Some of the more critical items are amplified in the following paragraphs.

Land and water resources must be available. Obviously new crop establishment will be facilitated when established crops are in surplus and prices are low. A marketable new crop adapted to land lying idle for a portion of the growing season has a good chance of success.

Availability of seed of superior varieties has been critical to most new-crops programs. Initially, at least, either government or a sponsoring company must provide seed of high quality at a fair price.

A need for expensive and highly specialized farm machinery for a new crop may discourage farmer acceptance. Either government or a sponsoring company may need to develop the necessary machinery and make it available at a reasonable price. For example, the state of Nebraska provided castor bean harvesters for farmers in an attempt to develop the crop about 30 years ago.

Agricultural research programs on new crops have suffered from lack of support or from intermittent support by both government and companies. In large measure this is because a new crop has no constituency and no organization to serve as a spokesman to or in legislatures. This handicap is likely to be overcome only through a strong research program, aided by the efforts of commodity champions, and supported by legislation that establishes and protects a long-term funding base.

Associated with the research must be agricultural information programs, particularly information for farmers. In the initial stages of adoption of a new crop, farmers' interest is increased if the crop sponsor provides field staff who are available on short notice and who can provide accurate information on all phases of production. Crop management skills required to produce profitable yields must be known if success is to be achieved.

Procurement, involving resources, supply, and financing, is critical to both the farmer and the processor. New crops have been most successful where farmers have been guaranteed a market and a price that will yield a profit.

Processing is extremely critical where the crop or crop product is new. For example, removal of rubber from guayule requires special processing equipment that is not of value in the processing of other farm crops. Furthermore, because of the bulkiness of the plant material and its deterioration with time, processing and production must be in close proximity, and harvesting and processing must be in balance. Finally, disposal of by-products may be a problem.

Market research and development almost certainly will be required, even though the processed commodity may be well known elsewhere. For example, acceptance of sunflower oil in the United States was slow because it was new to the American diet.

One final note concerning the systems nature of the process is in order. All subsystems must be in the "go" condition for the entire system to be in that condition. Attempts to commercialize a new crop with some subsystems in a "no go" condition are likely to lead only to frustration.

If all the components for a new crop are physically possible, the next question to be raised is whether they are economically feasible. If an established crop can provide a similar but cheaper finished product, the new crop is not likely to become established. Unless the new crop offers the farmer a profit potential as great as that from other crop choices, the crop is not likely to be produced. In the early stages, no one knows what the real cost of producing, processing, and marketing a new crop will be, but both the target market and the projected value of the product must be kept clearly in mind at all times.

Options for Implementing Strategies

The profit motive is important in encouraging the adoption of new crops by farmers, and appropriate perspective is important in motivating the adoption of financial support programs for new-crop research and development. The value of the U.S. soybean crop to farmers in 1981 was $12.1 billion, and the value of the portion of the crop exported was $5.6 billion (U.S. Department of Agriculture, 1983). The share of new-crop research within the U.S. Department of Agriculture budgeted for 1984 was $2.95 million (Office of Technology Assessment, U.S. Congress, 1983). The total expenditure for all new-crop research and develop-

Table 3. The Production-Marketing-Consumption System Decision Matrix (Knox and Theisen, 1981)

Component Description	Physically Possible	Economically Feasible	Institutionally Permissible
- Production Subsystem -			
Land and water resources			
Production financing			
Pest control			
Seed availability			
Fertilizer needs			
Input procurement			
Farmers' risk taking			
Farm machinery needs			
Farm energy requirements			
Input information			
Government services and regulations			
Agricultural research programs			
Agricultural information programs			
Crop organizations			
Farm labor needs			
Market information for farmers			
- Marketing Subsystem -			
Procurement:			
Procurement resources			
Dependable supply			
Procurement financing			
Government services and regulations			
Market intelligence			
Transport and storage			
Processing:			
Processing resources			
Processing equipment			
Commodity institutions			
Processing energy			
Processing research			
Processing information programs			
Processing by-products			
Managerial ability			
Distribution:			
Distribution resources			
Distribution financing			
Product market information			
Product transportation			
Market research and development			
Government services and regulations			
- Consumption Subsystem -			
Market p[illegible]ation			
Market size			
Consumer awareness			
Product versatility			

ment projected for 1984 thus amounted to 0.02% of the value of the soybean crop produced in 1 year from previous research and development efforts applied to that crop.

Several options are available to carry out the strategies for new-crop evaluation and development. These include the following, which may be used singly or to some extent in combination, as well as others.

Do Nothing New

"Do nothing new" is essentially what has been happening for the past 15 years. Pursuing this option would perpetuate the current situation in which development of most new crops is a slow process because of the absence of a commitment to sustained effort and the inability to bring together the various disciplines needed to carry out all aspects of the work.

Increase Support for Existing Programs

New-crop development programs are a continuing if minor effort at many state and private agricultural experiment stations throughout the country. Currently amaranth, paddy wild rice, Jerusalem artichoke, Tangier pea, quinoa, white lupine, fodder beet, cattail, and many other plants are in various stages of development as crops in different locations.

One alternative to speed the development of new crops would be to increase the federal funding of decentralized research, such as that now in progress, with realistic provision for long-term commitments and multidisciplinary efforts. Because individual states may benefit preferentially from new crops that are well adapted to conditions within their borders, states could be encouraged to increase their commitments by offering the funds on a matching basis.

Expand U.S. Department of Agriculture Efforts

At present, the work of the U.S. Department of Agriculture is almost at a standstill on the chemistry of new crops; the potential of the various products for food, feed, fiber, industrial, and medical purposes; and the processing and utilization of the products. The $2.95 million budgeted for 1984 for new-crops research within the U.S. Department of Agriculture (Office of Technology Assessment, U.S. Congress, 1983) amounted to only 0.3% of the combined state and federal appropriations for agricultural research in 1983.

New-crops research is not well supported in most states. Much of the funding that permits state researchers to conduct work on new crops is received as short-term competitive grants. To be successful in competition, the proposed research projects often must be finely focused and not necessarily the kind of integrated, continuing work that is most effective in new-crop development.

Because the U.S. Department of Agriculture has the capability to sponsor the broad range of activity and to assemble the various kinds of scientific expertise needed for new-crops research and development, additional funding for such work through the Department would appear to be a logical alternative. The required commitment of continued stable funding, however, must be developed either internally in the U.S. Department of Agriculture or externally in the form of specific legislation. Although sufficient discretion may exist in allocation of research funds within the U.S. Department of Agriculture to permit increased support of new-crops research and development, the very limited support given to this area is not a consequence of overfunding of other research. Agricultural research in general is underfunded in relation to the returns it has produced for the public. Moreover, both the U.S. Department of Agriculture and the Congress must answer to the constituencies associated with other projects, and the Congress has the additional problem of a short planning horizon characteristic of the political process. Research on new crops is a long-term proposition. To be most effective, the funding needs to be stable and adequate to support the broad-gauge program needed for success with the potential crop or crops being developed.

A sufficient increase in funding of new-crops work could allow the pursuit of research and development activities on a wide array of potential new crops. Research on a number of crops is important because many potential new crops may never reach the stage at which their economics justifies their production as commercial crops. If many potential crops are studied in an adequate way, at least one should be successfully commercialized, and this success should help to justify the prior efforts and maintain faith in the possibility that further successes are worth seeking. Increased funding of the U.S. Department of Agriculture also could provide indirect support for active participation of university scientists through cooperative agreements, foster multidisciplinary research efforts outside the Department, facilitate the generation and dissemination of plant resources and use information, and enhance the collaboration of public and private entities.

National New-Crops Coordinating Council

Successful and timely development of new crops requires sustained and coordinated efforts of researchers, producers, and processors. Furthermore, a credible source of information relating to market demands and product availability, quality, and costs is needed. One way of providing these is to establish a National New-Crops Coordinating Council.

This Coordinating Council would be established by the federal government as an independent, joint government-industry entity composed of representatives of research organizations, agricultural producers, processing and marketing interests, and consumers. The Council would serve as a clearing house for information regarding crop resources, availability, quality, and uses; production and processing methods; market demands; and product costs. It would also maintain directories of individuals and organizations with interests and expertise in particular new crops and products. It would sponsor workshops and conferences to exchange information, and it would encourage research and development in areas considered promising. It would not conduct research, nor would it fund research, but it would assist researchers in finding funding sources, and entrepreneurs in identifying potential enterprises.

National New-Crops Institute

The National New-Crops Institute concept represents an additional step beyond the Coordinating Council toward stimulating research on and commercial adoption of new crops.

The Institute, established by the federal government as an independent entity composed in the same manner as the Coordinating Council, would conduct research, train technicians, and provide assistance to entrepreneurs in evaluating and implementing potential enterprises. The Institute hopefully would be funded in part by donations from industry. Funds allocated by the Institute to research organizations could be supplemented by funds obtained by those organizations from other sources.

The amount of federal funds to support the Institute could be based upon gross farm income, the cost of controlling surpluses of field crops, or some other index, with the amount allocated in any one year to be spent over a period of, say, 10 years. This procedure would reduce fluctuations in funding from year to year and would provide relatively stable long-term support. The reason for including the cost of controlling crop surpluses as one of the possible bases for funding is that an important purpose of new-crops research is to find crops that would be competitive with the current crops for land but not for the product produced. Such crops would reduce the acreage of crops in surplus and would reduce the costs of surplus control.

Development Incentives

Even with the best of research and the most credible information, it is necessary that production of new crops by farmers be coordinated to provide at the right time the quantities processors can use. Without this coordination processors face uncertain supplies, and growers face uncertain markets. These uncertainties may pose an unacceptable risk for either or both. A National New Crops Institute, or other government programs, could reduce this risk by offering incentives to producers and processors who would agree to participate in well coordinated development plans.

One possible incentive to producers could be permitting them to grow potential new crops on "set-aside" land withheld from production of surplus crops. This alternative should be effective in stimulating production if the new crops could be grown without penalty.

Loans to producers could be guaranteed by the Institute on the basis of reasonable expectations of yield, quality, and price. Similarly, loans to processors could be guaranteed by the Institute on the basis of reasonable expectations of quantity, quality, and price of raw product to be available for processing. The Institute could guarantee further that a specified quantity of processed product could be marketed at a specified price.

Such loan guarantee programs could be useful in stimulating production. If they were not carefully attuned to physical and economic reality, however, they could result in surplus production or perpetuation of an otherwise unprofitable industry.

Tax incentives also could be used to stimulate development. But tax incentives provide fewer opportunities than do the loans described in preceding paragraphs for careful coordination of the quantity and timing of production; hence, more risk would remain. Moreover, the risk of stimulating surplus production or a dependent industry would be greater with tax incentives than with loans.

Exclusive release of new-crop varieties could be a stimulus to development. Producers will accept some development responsibilities if they receive the opportunity for potential profit associated with exclusive access to improved varieties. This type of arrangement was made in 1984 between the Oregon Agricultural Experiment Station and the Oregon Meadowfoam Growers Association.

Regardless of the origin, it is important that economic incentives exist for all groups involved in the commercial production and utilization of a new crop. Only as these exist will the potential for the new crop be realized.

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Appendix: Selected New Crops

A. Soybean

Until two decades had elapsed in the 20th Century the soybean (*Glycine max* (L.) Merrill) was considered a minor crop and, to many, not a very promising candidate for permanent status in U.S. agriculture. Yet the first introduction of soybean had been made in 1765, before the founding of the United States as a separate nation. At first a curiosity and later a forage or cover crop, soybean became a major source of both oil and seed protein during World War II. It is now one of the three major U.S. crops. In 1980-1982, wheat and corn were first and second in area harvested, and soybean was third. In the same years, corn was first in value of production, and soybean was second.

Truly a success story, soybean's history illustrates some important points:

• Increasing need for margarine oil created a need for vegetable oil during the 1920s.

• The one- and two-row combine became available in the 1930s, and this made soybean grain production practical.

- Germplasm collections and their subsequent evaluations in the early years of the 20th Century provided the research base for the development of improved varieties and their rapid rise to importance in the 3rd and 4th decades.
- Production research by different classes of specialists greatly increased the productivity of the crop.
- First-rate utilization research provided for improved products from both the meal and the oil, thus expanding markets.
- A true commodity champion, Mr. A. E. Staley, made critical commitments to the crop in the form of investments in processing facilities.

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B. Sunflower

Native to North America, the sunflower (*Helianthus annuus* L.) was domesticated about 3,000 B.C. and was utilized for food over much of the present United States at the time the first European settlers arrived. Imported to Europe, probably in the 16th Century, it was first grown as an ornamental and as a nut. In the 18th Century the seed was first processed for oil, and by the end of the 19th Century it had become an important oilseed crop in Russia.

Sunflower has become an important U.S. crop for domestic use and export, and it has created many new businesses and additional employment. Critical to this successful development were:

- Continuing research on cultural practices, variety testing, weed control, and uses at a few state agricultural experiment stations in the 1950s and 1960s. This work encouraged the development of small companies that processed nonoilseed sunflower for birdfeed and human food.
- Introduction of high-oil Russian varieties by the U.S. Department of Agriculture and testing of the seed by the Minnesota Agricultural Experiment Station.
- Trading of corn and other crop germplasm to Russia for high-oil sunflower varieties by U.S. companies and use of these varieties until about 1973, when they were replaced by U.S. hybrids.
- Construction of factories to extract oil from sunflower seed, beginning with one in Minnesota in 1967.
- Strong industry support for a wide spectrum of research and developmental work on oilseed sunflower.

Nonoilseed sunflower exceeded oilseed sunflower in acreage until 1972, when 510,000 acres of oilseed and 209,000 acres of nonoilseed varieties were grown. Oilseed acreage subsequently increased to more than 5 million acres in 1979, while nonoilseed acreage increased to more than 300,000 acres in 1981.

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C. Oilseed Rape and Mustard

Together, oilseed rape and mustard rank worldwide as the 4th or 5th most important source of vegetable oil, much of it used for edible purposes. In Canada, thanks to excellent coordinated research programs covering genetic improvement, production practices, utilization, and marketing, rape (*Brassica napus* L.) and turnip rape (*B. campestris* L.) together rank second to wheat in importance and are a major source of oil and protein in the nation's economy. Canada is now the world leader in export of oil derived from rape. In the United States, rape species are grown as oilseed crops on only a few acres. Less than the time of one scientist per year is devoted to their improvement. (In southeastern United States, however, turnip and mustard are grown widely for greens, and the technology and pest control techniques to produce the crops for this purpose have been developed.)

The success of the oilseed crops in Canada resulted in large measure from the following:

- Adapted varieties of rape and turnip rape were developed, and the crop rose to major importance in western Canada in the 1950s and 1960s.
- Through genetics and plant breeding the oil was improved in quality for food by eliminating erucic and eicosenoic acids. The meal was rendered safe and nutritious for livestock by major genetic reductions in levels of the toxic glucosinolates. The modified varieties are classed as a new crop called canola.
- Strong industry and public support of research permitted long-term commitments of scientists of many disciplines to improvement of the crop.

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D. Crambe

Crambe (*Crambe abyssinica* H.), a member of the mustard family, is an annual plant that grows wild in the Ethiopian highlands and North African plains. It produces an oil in which erucic acid is an important fatty acid component. The oil has many potential industrial uses, including: a lubricant in the continuous casting of steel and other metal-forming operations; a spinning lubricant in the textile industry; a source of derivatives that blend with natural and synthetic rubber to increase the elasticity; and a glossy wax following hydrogenation.

Derivatives of erucic acid have many commercial uses. Most oil with high levels of erucic acid has been obtained from rapeseed, but that supply now is less plentiful as a result of the development of erucic acid-free types.

Crambe is widely adapted. It can be grown as a spring crop in the Pacific Northwest and the Corn Belt or as a winter crop in Texas.

The major problems in establishing crambe on a commercial basis are procurement of high quality seed; coordination of production, processing, and marketing; utilization of the meal, which has high levels of toxic glucosinolates; and, because of the small acreage in the pilot plantings, inability to obtain the information required to elicit the Environmental Protection Agency's approval to use the herbicides needed. The experience with crambe clearly illustrates how important it is to have all the components of development in the "go" condition.

Reference

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E. Jojoba

Jojoba (*Simmondsia chinensis* (Link) Schneider) is a long-lived shrub with deep tap roots that is native to desert areas of northwestern Mexico and southwestern United States. It grows where temperatures do not fall below 15° F, annual rainfall is 3 to 18 inches, and soils are well drained. It has high tolerance to salinity and alkalinity. Some 30,000 acres of jojoba are being grown in southern California, Arizona, and Texas.

The seed oil is a liquid wax similar to sperm whale oil. Most of the current supply of jojoba oil is being used in the cosmetics industry. With a larger supply and a lower price it could provide an ingredient of superior lubricating oils for automobile transmissions. It can be hydrogenated to form a soft cream useful in polishes or a hard wax useful in the production of candles.

One problem in commercial development is the long time (5 to 7 years) before a jojoba plant will bear enough seed to harvest. To provide for harvesting the seed mechanically, the plant must be trained or pruned to form a narrow hedge or group of branches at the base with the shrub-like form about 4 feet above the ground.

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F. Meadowfoam

Meadowfoam (*Limnanthes alba* Benth.) is the most promising of several species of *Limnanthes* that are native to northern California and Oregon. It is a low-growing, herbaceous winter annual adapted to poorly drained soils. Interest in the domestication of meadowfoam followed studies at the U.S. Department of Agriculture's Northern Regional Research Center at Peoria, Illinois, which showed that more than 90% of the fatty acids in the oil are long-chain types with 20 to 22 carbon atoms in the molecular chains. By appropriate chemical treatments, ester compounds with 40 to 44 carbon atoms can be formed. These compounds have properties similar to those derived from jojoba (Appendix E).

Initial collections were made in 1962, and the more promising were grown at Corvallis, Oregon, in 1966. A variety called Foamore was developed from a single-plant selection made in 1970. Further improvements are being made, particularly in resistance to shattering of seed.

Production practices from planting to combine-harvest have been developed, and oil removal can be achieved by crushing or solvent procedures. The greatest needs are for further research and development, and obtaining federal approval for use of selective herbicides.

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G. Kenaf

Kenaf (*Hibiscus cannabinus* L.), a fast growing tropical or semitropical annual plant, is a member of the same plant family as cotton and hibiscus. For many years the fiber in the bark has been extracted by retting, like that of jute, hemp, and flax, and it has been used in the manufacture of cordage. Major production for this purpose is in Thailand, India, and China. Removal of the fiber by retting is too labor-intensive to permit kenaf culture for cordage fiber in the United States.

Good quality chemical pulps and newsprint can be prepared from kenaf. The yields of fiber from kenaf at present are slightly less than those from pulpwood, but kenaf is said to require significantly less energy for pulping.

A number of individual companies and organizations, including the American Newspaper Publishers Association, the Technical Association of the Pulp and Paper Industry, and Kenaf International have actively sought information or made test runs with kenaf in the last two or three decades. Most of the overall coordination and catalysis, as well as the initial impetus, have come from the U.S. Department of Agriculture's Northern Regional Research Center at Peoria, Illinois. A number of daily newspapers in various sections of the country have had trial editions printed on kenaf paper. Kenaf International is currently active in promoting the crop. Though there is now no commercial acreage in the United States, seed increase is occurring, and several hundred acres have been planted each year for the past several years.

A kenaf fiber pulp mill, constructed in accordance with research information developed in the United States, started operating in Thailand in 1981. This mill uses about two-thirds of Thailand's kenaf production. The possible use of kenaf for pulping is under consideration in many countries.

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H. Guayule

Guayule (*Parthenium argentatum* G.) is a perennial shrub native to desert areas of north central Mexico and southwestern Texas. Rubber is produced in stem and root tissue as small globules within cells. The globules are removed by finely grinding the stems and roots to break the cells; the globules coalesce in a liquid medium. The quality of the rubber is essentially equivalent to that obtained from the rubber tree.

Because natural rubber is critical to U.S. security and to U.S. industry, and because of the large amounts imported (Table 1), there has been interest in guayule's domestication and improvement through breeding. Research by the U.S. Department of Agriculture during World War II and more recent cooperative research by the U.S. Department of Agriculture and certain states show that the area of adaptation can be expanded, the yield increased, and the rubber content raised. Production practices are being improved.

More must be done on processing and marketing research and development, particularly with reference to disposal of byproducts, principally waxes, resins, and bagasse. Because of the bulk of harvested plants and the need to process freshly harvested material, processing and production must be in close proximity. The price of imported natural rubber will have a powerful influence on guayule's future, particularly with respect to gaining interest and support from industries that use rubber.

Reference

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I. Cuphea

Species of *Cuphea* produce oils differing greatly in fatty acid composition. This was discovered more than 20 years ago by U.S. Department of Agriculture scientists at the Northern Regional Research Center at Peoria, Illinois. Of particular interest are those species with high levels of medium-chain saturated fatty acids, including myristic, with a molecular chain 14 carbon atoms in length; lauric, with 12 carbons; capric, with 10 carbons; and caprylic, with 8.

At present, large amounts of coconut and palm kernel oils are imported into the United States and other industrialized countries to provide lauric acid for manufacture into soaps, detergents, lubricants, and other products. Derivatives of caprylic and capric acids have important applications in medical, nutritional, and dietetic fields. If cuphea could be domesticated to provide varieties with high seed yields, there would be tremendous commercial interest in it. Some species have been used as ornamentals.

Initial efforts to evaluate and domesticate cuphea began about 10 years ago at the University of Göttingen in West Germany. Currently agronomic and genetic research in the United States is underway by the U.S. Department of Agriculture at Phoenix, Arizona, and Beltsville, Maryland. At Corvallis, Oregon, a species evaluation and breeding program is supported jointly by Oregon State University, the U.S. Department of Agriculture, and companies interested in developing a source of medium-chain fatty acids in the United States. Germplasm collections and taxonomic studies have been made cooperatively by Kent State University in Ohio, the U.S. Department of Agriculture, and industry.

Obstacles to be overcome in adapting cuphea to commercial production include: premature shattering of seed; a long flowering and ripening period; seed dormancy, leading to poor germination; and sticky glandular hairs on the stems, leaves, and flowers, which complicate harvesting. Because of these obstacles and because of the high value of the oil, it is extremely important that the research on cuphea be continued over a period of at least 10 years.

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J. Buffalo Gourd

Buffalo gourd (*Cucurbita foetidissima* HBK) is a perennial cucurbit indigenous to the arid and semiarid regions of western North America. The association between the aboriginal Americans and the buffalo gourd existed for as long as 9,000 years. Although it was never a cultivated plant, it was an excellent "camp follower."

The fruit is usually round, with a diameter of 2 to 3 inches. The number of seeds per fruit ranges from 200 to 300, with an average weight of 4 grams (0.14 ounce) per 100 seeds. The seed contains 30 to 40% edible oil and 30 to 35% protein. Yields of seed may average 1800 pounds per acre. The large storage root contains about 18% starch on a fresh weight basis. Root yields of 18,000 pounds per acre appear reasonable.

Reference

Hogan, L., and W. P. Bemis. 1983. Buffalo gourd and jojoba: Potential new crops for arid lands. Advances in Agronomy 36:317-349.

Senator ABDNOR. Gentlemen, I do not want to interrupt, but before Mr. Knowles starts, I want to tell you how much we appreciate your being here. I do not think we could have brought in a qualified group of people, who are as unique in the expertise, to testify for the record. It will be extremely valuable not only to this committee, but the Committee on Agriculture, who will be writing in 1985 a new farm bill for 1985. All of us feel that agriculture has come a long way since the first farm bill was on the record and yet we have been staying close to that. I cannot think of anyone more qualified to help us lead the way than this group of people here today. We do thank you and, Mr. Knowles, go right ahead.

STATEMENT OF PAUL F. KNOWLES, PROFESSOR EMERITUS OF AGRONOMY, UNIVERSITY OF CALIFORNIA, DAVIS

Mr. KNOWLES. Mr. Chairman, as Mr. Black has pointed out, for most of my professional life I have worked on new crops. As a consequence, I am very pleased to be picked as a member of the task force to prepare a report on new crop development. In my testimony here this morning, I shall have the viewpoint of a biologist. Mr. Blase and Mr. Sampson will discuss the report from their viewpoint.

In this oral testimony, I shall just emphasize a few points that I consider important.

Point one: New crops have added to the productivity and flexibility of agriculture. All of us are aware of the fact that soybeans were a new crop some 60 years ago and has added greatly to the supply of vegetable oil and protein meal in this country. In Canada, rapeseed in the last 20 or 25 years has had similar history to soybeans in the United States, and now supplies much of their vegetable oil and protein feeds needs. In south central Spain, sunflower has been developed as a replacement for summer fallow and supplies a great deal of their vegetable oil. In other words, new crops have increased the crop options available to farmers thus adding flexibility to agriculture.

My second point: New crop development has been a slow and haphazard process. Soybean, which was first introduced to the United States in 1765, did not become an oilseed crop until the third decade of this century. Sunflower was domesticated by the American Indians and only in the last 20 years or so has become an oilseed crop in the Northern Great Plains. Safflower had good reports in California at the turn of the last century, yet it became a commercial crop only in 1950. In other words, the evidence emphasizes that new crop development should be accelerated.

My third point: Many species have not yet been evaluated. Of the approximately 300,000 species of higher plants, only about 3 percent have been evaluated. However, for a period of about 20 years, beginning in the year 1957, the Department of Agriculture took the leadership in evaluating some 8,000 species for their potential value as crops in American agriculture. Unfortunately, that program has been scaled down and is almost nonexistent at the present. Furthermore, there has been essentially no followup research and development on crops that are promising in that program.

My fourth point: New crop development takes different forms, several disciplines, and many years. There are three avenues to new crop development which are:

First: Domesticating a wild species.

Second: Adapting a domesticated species to the environment of the United States.

Third: Modifying an established crop species in the United States to produce new crop products.

First: New crops by domesticating a wild species. Mr. Sampson will discuss this in some detail using the species of interest to him. I want to make only one point. The evolution of corn, wheat, and other established crops required a period of hundreds and perhaps thousands of years, and now we, as breeders and developers of new crops from wild species, are trying to compress that development into a period or 20 years or so. It is a difficult task.

Second: New crops from adapting domesticated species to a new environment. The report refers to soybeans, sunflower, safflower, and other crops that were domesticated before they were developed as new crops in the United States. While the stages of their development are similar to the domestication of wild species, the process will take much less time.

Third: New crops by modifying an established species to supply new products. I have been involved in this with safflower prior to retirement. However, the classic example of this is the work in Canada on rapeseed. The original rapeseed had high levels of erucic acid in the oil. This was a component of the oil that was undesirable. Canadian plant breeders reduced this to zero, and the resulting oil now is equivalent to soybean oil quality and utilization.

In a similar way, they reduced the toxic glucosinolates in the meal. These are toxic to livestock and humans. These were reduced by genetic means. Now the meal is almost equivalent to soybean for livestock feeding.

In safflower in California, we found a mutant type that, instead of having high levels of linoleic acid in the oil, had high levels of monounsaturated oleic acid. Thus, we were able to put into the marketplace a second safflower oil. The same process is taking place in sunflower. There will be commercial varieties of sunflower available soon that will be almost pure for oleic acid. This will be an oil that will change the status of sunflower in this country.

These changes in oil composition are in terms of the fatty acids that are already present. I think the future will see the addition or the development of vegetable oils in established crops that have different chemical compositions. For example, we may be producing essentially a coconut oil from sunflower. This seems far out, but the possibility is there.

Point five: Modern biotechnology will aid in new crop development. Before the meeting, I met Mr. Ralph Fraley from the Monsanto Co. in St. Louis, who is a molecular genetist, and is certainly much better qualified than I to comment on this. However, I feel that biotechnology has a role to play in this process of domestication and improvement of new crops.

The main role of biotechnology, I haven't time to go into the details, will be to expand the variability in species, to give the plant breeder more to work on. It may speed up the process of getting

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over some of the major hurdles in domesticating the species. Hurdles such as seed shattering and seed dormancy and other undesirable features.

Biotechnology will permit the crossing of very different species through embryo culture and protoplast fusion. However, while biotechnology is going to increase the variability and give the plant breeder more material, it will not substitute for field testing. It is a difficult task to evaluate this expanded variability to find the materials most desirable.

Finally, my sixth point: There are hazards in new crops development. I see this from the point of view of the biologist, recognizing the many features that are required to be changed to put a new crop into production.

We expect that there will be failures, probably more failures than there are successes. This is true in product development in industry. There may be one success for 20 failures. This emphasizes the point that we should be looking at a number of new crop possibilities in case one fails perhaps the next will succeed.

Another word of caution is that some proposed new crops actually became weeds in our agriculture. We can think of quackgrass, Johnson grass, the multifora rose, and others. It, certainly, behooves the people working on new crops to assess them from the point of view of their being potential weeds.

Another point I would make in this regard is that there have been many examples of unwarranted commercial development of new crops. Development long before they have been properly assessed. These usually lead to failure, financial losses, particularly loses to farmers, and have given new crop development a bad name in many locations. It is certainly important that we properly assess new crops prior to their release in commercial production.

I was going to say something about the options that the task force developed by way of a conclusion to their report. However, I am going to defer that honor to Mr. Blase who will succeed me. I know that has been working in this area a great deal and he is well qualified to provide details.

Again, I want to say thank you to the committee for giving me an opportunity to present some of my viewpoints on new crop development.

[The prepared statement of Mr. Knowles follows:]

PREPARED STATEMENT OF PAUL F. KNOWLES

New-crop development in the United States has been a slow process. Examples are: soybean, which was first introduced in 1765, and became a commercial oil crop in the third decade of this century; sunflower, which was domesticated by the American Indians, but became a commercially grown oil crop in the U. S. in the last 20 years; and safflower, which received a good report in California tests in the first years of this century, but was commercially grown in that state for the first time in 1950.

Only a small fraction of the approximately 300,000 species of higher plants have been evaluated for their potential as sources of products useful to society for food, feed, fiber, industrial products, pharmaceuticals, pesticides, and soil and water conservation. For a period of about 20 years beginning in 1957, when funds were available, the U. S. Department of Agriculture assumed leadership in the evaluation of some 8,000 species. Unfortunately that program currently has a very low priority. Even among species with some promise, there has been very little follow-up work in terms of developing types adapted to commercial production.

CAST Report No. 102 has examined new-crop development from the points of view of: why a need for new crops; procedures in their development; strategies in development; and options for implementing strategies. As chairman of the task force that prepared the report I am grateful to both its members who made important contributions to the report, and to Dr.

C. A. Black, Executive Vice President of CAST and his staff who put the report in its final form. I shall review the report from the point of view of a biologist. Drs. M. G. Blase, an agricultural economist, and R. L. Sampson, a chemical engineer, will also review the report.

WHY A NEED FOR NEW CROPS

Most of the needs for new crops relate to economics or products, so will be considered by Drs. Blase and Sampson. As a biologist I see a need for new crops to reduce the vulnerability of American agriculture to:

- Reduced water supplies. There is a need to develop "crop plants with low water requirements, tolerance to drought, or the capacity to complete their life cycles quickly when moisture is available."

- Increased soil salinity. As salinity increases both in irrigated areas and in some of the dryland areas of the northern Great Plains, there will be a need for crops with greater salt tolerance.

- Air pollution. Near cities there will be a need for crops tolerant of pollutants, and in areas where open-field burning is prohibited, there will be a need for substitute crops.

- Soil erosion. There will be a need for crops that resist soil erosion for some prime agricultural land, for deep cuts on roadsides, and for abandoned mine land.

- Pests. More attention is being given to crop choices in integrated pest management programs.

There is also a need to identify and develop new crops that will increase productivity through:

- Double cropping. In more areas with very long growing seasons or mild winters it may be possible, by developing short season new crops, to grow two crops each year instead of one.

- Crop substitution for fallow land. The report mentions the successful use of sunflower in Spain as a substitute for summerfallow, and the use of brown mustard as a substitute for winter fallow in southern Pakistan.

- Increasing crop choices. This would increase the flexibility of agriculture, making it more responsive to market demands.

NEW CROP DEVELOPMENT

There are three avenues of new-crop development, which are:

- Domesticating a wild species.
- Adapting a domesticated species to a new environment.
- Modifying an established crop species to supply a new product.

New crops by domesticating a wild species

In the evolution of the crops grown commercially at the present time, a great deal of time was involved. Among the variability provided by nature, primitive societies selected types which had higher yields, larger seed or fruit size, improved flavor, resistance to seed shattering, and better adaptation to the environment. In addition the established crops have benefitted from 50 to 75 years of intensive breeding programs. On the other hand, modern programs of new-crop development are attempting to compress evolution into a period of a few years. It is evident that programs of new-crop development must be supported on a sustained basis for periods of at least 10, and preferably 20 years. Fortunately the plant breeder now has techniques of mutagenesis and genetic engineering which should shorten the process.

The report has outlined the stages involved in the domestication of a species. Obviously, the first stage is the collection of a large range of germplasm. Related species may be collected also. One or two years may be required initially, with follow-up collections being made later as more is learned about the species.

The second stage is evaluation of germplasm, usually requiring hundreds, even thousands, of small plots. Evaluations are based on field performance, plant and seed morphology, and quality of the product. Two or more years may be required. The purpose is to identify superior germplasm for more exhaustive tests and for inclusion in a breeding program.

The third stage, actually a stage continuing through all of a new-crop development program, is product evaluation. This is critical because, if there will be no market for the product, or if the product can be obtained cheaper from another assured source, there will be no useful purpose served in continuing with the development of the crop.

The fourth stage involves exhaustive tests of superior germplasm to identify the best environment for production, the best production practices, including dates, rates and depths of seeding, and the best harvesting procedures. This stage can take up to 10 or more years because it requires the cooperation of: agronomists (or horticulturists), often at different locations; pathologists and entomologists; experts in weed control; and agricultural engineers.

The fifth stage, involving plant breeding, will be initiated at the same time as, or shortly after the beginning of the fourth stage. This stage will include: selection of superior types from germplasm as it is being evaluated; and hybridization of superior types, particularly where they are superior in different traits, and selection in the hybrid populations. The mating system (whether the species is cross- or self-pollinated) will be determined, because it will govern the techniques of breeding that are used. Breeding will continue throughout the life of the program, as in the case of established crops.

The report did not emphasize that in domesticating a wild species there will be many hurdles that will be difficult to cross. Among them will be a long drawn-out period of seed production (indeterminate habit), seed shattering at harvest, and high levels of seed dormancy, all traits of value to the species in its wild state. Modern biotechnology will aid in overcoming these hurdles. Using appropriate mutagenic techniques, variability can be induced, hopefully including the elimination of the undesirable traits. Genetic engineers can reduce plant parts to single cells, then culture the cells and eventually regenerate plants, often inducing mutations in the process. Combinations of mutagenesis and regeneration from single cells will magnify variability. Wide crosses involving different species will be facilitated by modern techniques of embryo culture amd protoplast fusion. However, while modern biotechnology will increase the range of variability available to the plant breeder, as yet it cannot be used to produce change in only one or a few directions. It will not eliminate the need to evaluate the variability under field conditions.

Traditionally the USDA, universities and other public agencies have been involved in the above stages. In part this is because public agencies often provide scientists with skills in many disciplines. However, in later stages of crop development commercial companies increasingly have assumed the plant breeding role.

The sixth stage, production and scale-up, and the seventh and last stage, commercialization, take the program in large part out of the hands of the biologist.

Dr. Sampson will illustrate the process of new crop development using wild species of Cuphea as examples.

New crops by adapting a domesticated species to a new environment

The report refers to soybeans, sunflower and safflower, all crops that were already domesticated before they were developed as new oil crops in the United States. While the stages of development are the same as those given above for domestication of a wild species, the time involved can be much less.

New crops by modifying an established species to supply a new product

Three examples are referred to in the report. In rapeseed, the oil was greatly improved for edible purposes by the genetic elimination of erucic acid, a component of the oil, thus providing an oil similar to soybean oil. Toxic glucosinolates were also greatly reduced by genetic means, making the meal competitive with soybean meal as a livestock feed. In safflower the standard type provides an oil with high levels of the polyunsaturated linoleic acid and low levels of the monounsaturated oleic acid. By changing a single gene, the proportions of these two fatty acids were reversed, thus providing a new oil for the marketplace. Similarly in sunflower, a type with high levels of oleic acid is about to enter commercial production. Obviously the development of new crop products by changing a few genes is a simple matter, after the appropriate genes are developed or found.

These changes in oil and meal composition are in terms of amounts of components already present. The next stage, not mentioned in the report because it is speculative at this time, will be the addition of products not now present in a cultivated species. It may be possible by mutating genes to develop a sunflower with an oil resembling coconut oil which is much used in the soap and detergent industry. Speculating even further, it may be possible to add to sunflower the tuber-producing characteristics of the Jerusalem artichoke, a close relative of sunflower.

STRATEGIES FOR DEVELOPING NEW CROPS

Dr. Blase, because of his contributions to studies of the development of several potential new crops, and Dr. Sampson, because of his present involvement in the domestication and commercialization of Cuphea species, will address themselves to this subject.

OPTIONS FOR IMPLEMENTING STRATEGY

In offering options to implement a strategy of new crop development, the report does not make recommendations nor suggest a policy. It is obvious, however, that there was a strong sentiment among those who wrote the report that new crop research and development should receive more attention and support.

In suggesting options the report identifies the following needs:

- Increased or supplemental support for existing new-crop development programs nationwide.

- A greater involvement of the U. S. Department of Agriculture in new-crops research and development.

- A separate agency identified with, and allotted responsibility for, new-crop development, which would be a "joint government-industry entity composed of representatives of research organizations, agricultural producers, processing and marketing interests and consumers." One option was a National New-Crops Coordinating Council which would be a clearing house for information, would sponsor workshops and conferences, and would identify promising crop candidates for research and development. A second option was a National New-Crops Institute which would in addition conduct and fund research, and would train technicians and provide assistance to promising new-crop development programs.

CONCLUSIONS

From my perspective, if new crops research and development are given more support, it should provide the following:

- Integration of researchers, crop developers, processors and market developers.

- Nation-wide programs of research with involvement of both the U. S. Department of Agriculture and state agricultural experiment stations.

- A rigorous and early evaluation of a number of potential new crops, sufficient to identify those with commercial possibilities before too much time and money are spent on them and before unwarranted development begins.

- Long-term programs for promising new crops, with sustained support sufficient to provide for all phases of development, from germplasm collections to commercialization.

- Continuous monitoring and assessment of programs using the production-marketing-consumption (PMC) system.

I am pleased to note that President Reagan has signed into law (Public Law 98-284) the Critical Agricultural Materials Act, which is an extension of the Native Latex Commercialization and Economic Development Act of 1978 which provided for support of research primarily on guayule, a source of rubber. The Critical Agricultural Materials Act provides for a five-year program of research and development on guayule and a number of additional native species providing products of strategic and industrial importance. The Act also provides for a new office of critical materials to be set up by the U. S. Department of Agriculture which will coordinate research efforts nationwide. It will be administered by a Joint Commission with members from Departments of Agriculture, Commerce, Interior, State and Defense, the National Science Foundation and the Federal Emergency Management Agency.

Senator ABDNOR. Well, thank you, Mr. Knowles. We will be one of the beneficiaries and we thank you for coming.

Mr. Blase.

STATEMENT OF MELVIN G. BLASE, PROFESSOR OF AGRICULTURAL ECONOMICS, UNIVERSITY OF MISSOURI, COLUMBIA

Mr. BLASE. Thank you, Senator Abdnor.

Prior to discussing the alternatives laid out in the report, I would like to cover two other items. One of these has to do with the economic rationale for new crops. The second deals with the procedure for developing strategies for the establishment of new crops.

First, with regard to economic rationale, there are three principal reasons for our needing to be concerned about potential new crops.

One is the excess capacity that exists in the agricultural industry. The Center for National Food and Agricultural Policy at the University of Missouri at Columbia and Iowa State University recently has undertaken a 10-year projection. It suggests that we have somewhere in the vicinity of 26 to 30 million acres of excess capacity in the industry presently, at acceptable price levels with alternative cropping systems we know today.

There are various ways that we could express that excess capacity. The point is that we need new crops to utilize effectively that capacity.

The second point that I would like to make with regard to the economic rationale has to do with something that Mr. Knowles talked about. That is, to reinforce his statement about the inefficiencies of the system we have in place. This is apparent in the history of new crop establishment in the United States.

Consider some of the alternative ways new crops move in the development process. Frequently, a new species will be brought to the United States and there will be some experimental work done on it by the genetists. Perhaps the genetists will persuade some farmers to try growing some of the crop. But these farmers become disillusioned because of the fact that there is no organized market for the crop. Hence, the crop may well be forgotten for perhaps 25 or 50 years and then someone in industry, like Mr. Sampson, may find that there is a need for a product that could be produced from such a crop.

In turn, a firm may ask farmers under contract to produce this new crop. But they may become disillusioned because of the fact that there has not been any work done on pests or diseases and, as a consequence, may have an unprofitable experience.

It may take as long as 200 years, as occurred in the case of the soybean, before the crop ever, becomes established. Surely a country that has the management ability and capacity to put a man on the Moon should have the ability to come up with a more efficient procedure than the haphazard, disorganized one that we have had in the past.

The third point that I would like to make with regard to economic rationale has to do with the process of economic development. In his classic work a number of years ago, Joseph Schumpeter pointed out that there are several altenative ways we can expedite the development process. One of these is to develop new products. Another is to come up with new procedures for producing existing products.

Let me illustrate both of these if I might with new crops.

First of all, in the instance of a new product, I find it almost mindboggling to consider the potential of a nutritious snack food that might be produced from a crop like grain amranth. It is a small seeded crop that has the capacity to pop like popcorn but has an exceptionally well-balanced set of amino acids. So it is conceivable there could be a very nutritious snack food that could be added to our diet.

As an illustration of the second, I would like to suggest kenaf represents a potential way of producing newsprint that we have not been utilizing. This exhibit happens to be a newspaper that is almost 5 years old that was printed on kenaf newsprint. Kenaf is a crop that has considerable potential as an annual, renewable source of newsprint feedstocks.

We also have the possibility of import substitution in the instance of the production of natural rubber from guayule. We have the possibility of utilizing kenaf as a source of feedstocks that we are presently using.

Senator ABDNOR. How come that has not been in the forefront? How come we have not heard more about that?

Mr. BLASE. This is a very interesting development.

Senator ABDNOR. I would like to get that.

Mr. BLASE. First of all, the breakthrough that made it possible to produce kenaf is relatively recent. Approximately 20 years ago, USDA in the Research Lab at Peoria, discovered it was possible to use this as a source of newsprint material. That was a strategic breakthrough. But one breakthrough alone will not make it possible for the whole system to come into operation. As a matter of fact, it has only been in the last 5 years that an effort has been made to look at the total system, that is, consideration of going, if you will, the equivalent if this were cotton, from dirt to shirt. This is the point that I wanted to make with regard to a specific part of our report.

We maintain there is a need for a production-marketing-consumption system to be considered in the production of new crops. It is not satisfactory for us merely to find it is physically possible to produce these things, but we also have to determine when it is economically feasible to do so and when it is also institutionally permissible. Each one of the component parts of the process—from providing the inputs along the way including not just agricultural production, although it is an important subsystem in the PMC system, but in addition, the marketing subsystem with the processing technology and with the consumption subsystem with the marketing of the product at the retail level—needs to be considered as well.

It is a long, complicated process that needs to be put in place in a systematic fashion. In the past we have not been inclined to think of it as a systems process. We have been inclined to think of it as individual component parts, thinking that somebody else would put the rest of the system in place.

What we are suggesting is that with the PMC system it is possible to both organize information and also to put together a strategy for new crop development. Because of the fact there are lead times that are needed for some of the pieces of the system to be put in place, it is necessary for some kind of a "game plan" to be put in place in order for the efficient establishment of a new crop PMC system to take place.

The final thing I want to mention is that in the report we identify six different alternatives we would submit that are worthy of your consideration.

The first of these is that nothing new be done, nothing beyond what we have been doing in the past. This means a continuation of a haphazard, disjointed system.

Second, another alternative is to merely increase support for existing programs. This is to say, not to initiate new elements of the total system but to think in terms of only the kinds of things oriented particularly toward the genetic and some small amounts of processing research, but with essentially nothing new.

The third alternative would be to increase programs of the U.S. Department of Agriculture in this area. This, too, by virtue of the fact it tends to emphasize the public sector rather than consider the role the private sector needs to play jointly with the public sector, tends to have certain limitations.

The fourth alternative is the establishment of what we call a National New Crops Coordinating Council, a council that would be joint between the public sector and the private sector. They would assume responsibilities for coordinating, information servicing, legitimizing, seminaring, and so forth. One of the crucial problems with a new crop for any firm that is interested in establishing it is where do you get information about all of the component parts of the system. The information tends to be disjointed and difficult to obtain.

The fifth alternative would be essentially a National New Crops Coordinating Council with an additional function. That is, it would have the function of either doing or funding research on new crops. We choose to call this alternative a National New Crops Institute.

The final alternative which warrants consideration, regardless of the others, deals with the provisions of incentives. These incentives could range all the way from making it possible for farmers to experimentally grow new crops on set-aside acres under the commodity programs, to the provision of tax incentives, to the provision of loan guarantees to try to expedite this process.

In conclusion, it occurs to me as an agricultural economist that there are a number of things we would be well advised to do as the public representing the interests of the total society, if we are interested in economic development being expedited through this process.

An important part of this entire process is the role of industry and the whole processing perspective. I am going to turn to Mr. Sampson for that perspective at this point.

[The prepared statement of Mr. Blase follows:]

PREPARED STATEMENT OF MELVIN G. BLASE

I appreciate the opportunity to amplify on some aspects of the CAST Report entitled "Development of New Crops: Needs, Procedures, Strategies, and Options." In doing so, I would like to emphasize three things. First, the economic rationale for new crops will be considered. Second, the potential uses of the Production-Marketing-Consumption System (PMC) for the formulation of strategy will be elaborated. Third, and finally, the action alternatives outlined in the report will be discussed.

The Economic Rationale

From my perspective as an agricultural economist, there are three primary factors that constitute the economic rationale for efforts to further the establishment of new crops in U.S. agriculture. The first is the excess capacity in the industry. The second is the inefficient way in which resources are spent presently for the establishment of new crops. The third is the potential contribution to economic development, including consideration of our balance of payments problem. Each deserves elaboration.

Excess Capacity

The report touches upon the surplus capacity of U.S. agriculture as part of the rationale for the need for further work on new crops. Since the report has gone to press, more precise information has been made available in this regard. The Center for National Food and Agricultural Policy, located on the campuses of the University of Missouri-Columbia and Iowa State University, and funded by the U.S. Congress and others, specifies in its recently completed ten year forecast for the agricultural sector that approximately 26 to 30 million acres of excess capacity exist in the sector, given present cropping alternatives and acceptable rates of return to resources.[1] This forecast, published August 16, 1984, provides more specificity about a dimension of the problem, i.e., the extent of the surplus capacity in the industry, than does the CAST report. Clearly, that capacity could be described in other terms. However, the use of land as the indicator probably represents the most widely accepted measure of the bothersome problem of surplus capacity.

Undoubtedly, resources exist within the industry for the production of new crops if they could be identified in terms of their physical possibilities, economic feasibilities, and institutional permissibilities. These dimensions of new crops will be discussed subsequently when attention is turned to formulation of strategy for new crop establishment.

Present Inefficiencies

The second factor that I would like to expand upon with regard to economic rationale has to do with the inefficiencies inherent in our present procedures. At best, new crop establishment can be described as disjointed, unorganized, and inefficient. Although no empirical estimates have been formulated, to the best of my knowledge, to document the extent of this inefficiency there is little doubt of its existence.

Consider the likely phases through which a hypothetical new crop goes -- based on the historical experience of past "new crops". Initially, the plant is located in some other part of the world and is brought to the United States for experimental growing. Perhaps due to some specific characteristic that is found encouraging, a plant geneticist works with the plant and, perhaps, even encourages a small number of farmers to attempt growing it under semi-commercial conditions. However, very frequently this comes to naught because, among other things, no markets exist. Perhaps 25 to 50 years go by during which this particular crop is essentially forgotten, certainly in terms of actual production. At that point some industrial user may perceive the need for a product similar to what this plant can produce and, upon gleaning the literature, determines that the crop in question exists. After learning what had been done earlier with the crop, perhaps an effort is made via contract growing to get some farmers to produce it for the private firm. Very frequently these innovative farmers are likely to encounter such things as disease problems because no research has been done in the areas of plant pathology and entomology. Regardless of the specific pest involved, the crop suffers another setback. And on the story goes -- sometimes for 200 years, as was required for the soybean to become an established crop. In sum, the procedures now being used are highly discontinuous, quite unorganized, and, at minimum, make inefficient use of resources. Surely a country that has the management ability and resources to put a man on the moon, should have the capability to improve upon this type of record, in my estimation.

Economic Development

The basic rationale for the establishment of new crops is the improvement in the level of living that will result. In his classic work on the subject, Schumpeter identified several sources of growth. Included in these were new products and new methods of producing existing products. Both apply to new crops.

The potential for supplying ingredients for new medicines from new crops is a fascinating illustration of the first potential for development. Another, perhaps more realistic, potential is the possibility of producing a nutritious snack food from new crops. For example, the combination of its popping ability and its exceptionally well balanced set of amino acids makes grain amaranth a candidate feedstock for a more nutritious group of snack foods than presently on the market. While other illustrations could be given, I think that the point has been made that our level of living can be enhanced by new crops.

The second source of development, i.e., via new methods of producing existing products, can be illustrated by a number of potential new crops and their end products. Newsprint, produced from kenaf with less energy than required when produced from wood pulp, illustrates this point. Likewise, the production of a substitute for sperm whale oil via the jojoba plant enables society to accomplish some of its environmental objectives while not detracting from the accustomed level of living. Clearly, one of the potential "engines" of the development process is the establishment of new crops.

The final aspect of economic development worthy of note concerns potential import substitution. Present balance of payments problems dictate that the U.S. would be well advised to use some of its excess agricultural resources to produce substitutes for imports. Again, using kenaf as an illustration, the potential for reducing the size of U.S. imports of newsprint should be recognized. In addition, rubber produced from guayule could reduce imports of natural rubber or of petroleum feedstocks. Undoubtedly, the U.S. could attack some of its long run balance of payments problems with new crops.

The PMC Decision Matrix as a Basis for Strategy Formulation

On page 23 of the report, the Production-Marketing-Consumption Systems decision matrix is presented.[2/] In that matrix each of the subsystems is identified by component parts. Further, three questions are asked of each of these components. Is it physically possible to perform the function in question? If so, is it economically feasible to do so? And, finally, is it

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institutionally permissible to do so? All three questions for all of the functions must be answered in a positive fashion in order for new crop establishment to proceed rapidly. In many instances, this is not the case. Consequently, there is a need to formulate a strategy to overcome obstacles, be they physical, economic or institutional, to the establishment of the new crop.

By strategy is meant the process of following a time-phase sequence of predetermined activities, leading to a selected goal. That is to say, a "game plan" is formulated. Let us consider how this type of strategy might be developed for a particular crop.

Strategy Formulation

The first step is to consider whether each of the functions in the decision matrix is physically possible. There are several aspects of this question. Does the technology exist for performing the function required of each component? For example, are agronomic practices known that enable the production of the crop on a commercial basis? Does the processing technology for the crop exist? Are techniques for handling the final products from the crop known? In addition to the question of knowledge of physical possibilities there is also the question of whether the function can be performed even if the knowledge exists. This is analagous to the "development" aspects of "research and development". In many cases the function is physically possible because it is similar to and can be borrowed from a comparable one for another crop. But where borrowing is not possible, research and development are needed to determine how the function can be performed.

But just because the function is physically possible does not mean it will be performed. There must be incentives to do so. In the private sector there must be profit rewards to make the risks worth undertaking. In the public sector there must be public service rewards to both motivate those undertaking the functions and justify the continuation of appropriations to do so. Regardless, each and every function must be economically feasible in the sense of responding to incentives. Especially with new ventures such as new crops, the potential rewards must be appreciable relative to the investment risks.

The question of institutional permissibilities is not as obvious as those of physical possibilities and economic feasibilities. Several examples may help illustrate this concept that has both sociological and legal implications. Some farmers can be expected to be reluctant to raise grain amaranth because it is related to and looks somewhat like pigweed. The anticipated social pressure that can be exerted by neighbors can discourage farmers from planting "that crop that looks like pigweed". Another illustration comes from the pulping industry. There is some evidence that pulpmasters may be reluctant to pulp kenaf rather than wood. In their terminology they prefer to pulp wood not weeds. Finally, an example of legal problems is provided by the need for an EPA clearance for a herbicide to be used on a new crop. Suffice it to say, even if the functions in the PMC system are physically possible and economically feasible they may not be performed if they are not institutionally permissible.

Regardless of where in the matrix the constraints lie, a strategy is needed to overcome them in an efficient manner. Especially given the long lead times required to overcome some of them, a time-phased "game plan" is needed. The PMC matrix, therefore, represents the beginning point for strategy formulation for the commercialization of a new crop.

The PMC Matrix as a Means of Organizing Data Collection Efforts

In most cases a new crop is not totally new. That is, it is not totally unknown. However, much of the information about it frequently is scattered and not readily available to a central group of decision makers. As a consequence, the PMC decision matrix is useful in compiling data about constraints, regardless if they involve physical possibilities, economic feasibilities, or institutional permissibilities. For example, there may be data and/or experts available in a given part of the country who are aware of the agro-climatic conditions under which a given crop will perform well. On the other hand, in a completely unrelated discipline, organization and location, there may exist expertise that can identify the types of machinery needs that are required to harvest such a crop. Further, in the marketing subsystem there may be similar individuals, unknown to those mentioned above, who are aware of the types of processing research that need to be undertaken in order to make some of the plant's by-products marketable. Finally, in still another location, there may well be expertise with regard to how the final product from this plant could penetrate a given market. One of the functions that can be performed by the PMC decision matrix is to identify where these constraints exist as well as organize information about remedial measures for them. The methodology that has been developed in a recently completed study funded by the National Science Foundation has been that of using the Delphi technique, i.e., a survey procedure with feedback to respondents, to identify where the knowledge gaps are and the most logical means by which they can be remedied.[3/] This methodology can be used for other crops as well.

Having identified the constraints to the establishment of a new crop, be they physical, economic or institutional, a new crop establishment strategy can be formulated. That is to say, it is possible to identify specific activities that have to be performed in a given sequence in order to efficiently establish the new crop. Given the long lead times required to deal with individual constraints, the careful orchestrating of the process is essential for efficiency. Even with the best of efforts, given the uncertainties involved, a substantial amount of pragmatism will be required. However, the process should not be totally uncoordinated as now appears to be the case.

One of the best illustrations of this procedure is that of the experience with kenaf. In that instance, the PMC decision matrix was applied, the constraints were identified, a strategy for a new crop establishment was formulated, and an effort is being made at present to implement that strategy. Kenaf International, a relatively new firm, has been organized and is aggressively pursuing alternatives in this area at present.

Action Alternatives

The final thing I would like to emphasize from the report has to do with the alternatives or options that are available to facilitate the use of strategies for new crop evaluation and development. Beginning with page 24, six alternatives are outlined.

The first of these involves doing nothing -- nothing beyond what we are presently doing. Unfortunately, this has a greater cost than meets the eye. The cost takes the form of unwise investments in some aspects of new crops whose PMC system has not been fully developed.

The second alternative would be to increase support for existing programs. This would involve providing more efforts especially in the area of the agronomic aspects of new crop development rather than the total systems requirements as identified in the PMC decision matrix.

The third alternative would be to expand U.S. Department of Agriculture programs. Because of the fact that these are centered in the public sector, they, too, obviously omit certain aspects of the PMC decision matrix.

The fourth alternative would be to establish a National New Crops Coordinating Council which would have a coordinating, information servicing, seminaring, legitimizing function. As a joint private-public sector organization, this Council could work at the interface between the two in a cooperative manner rather than have an adversary relationship which easily can develop under present programs. The same is true for the fifth alternative.

The fifth alternative is the establishment of a National New Crops Institute which, like the National New Crops Coordinating Council, would be a joint public-private venture. But in this case, it would also have funds available for research on new crops.

The final alternative is important regardless of the others. It deals with the need for development incentives via such things as making available the use of set-aside land under present USDA commodity programs, loan guarantee programs, tax incentives, etc. These minimal procedures would facilitate, albeit in minimal fashion, the establishment and commercialization of new crops. Given the risks involved for private firms and the potential payoff to the public, such measures appear to me as an agricultural economist, to be entirely appropriate.

Clearly, there are alternatives available that could be undertaken if there is a desire to expedite the establishment of new crops in the U.S. agricultural sector.

Footnotes

1/ "Preliminary 10-Year Forecost of the Agricultural Sector Using a Floating Average Loan Rate." Center for National Food and Agricultural Policy. University of Missouri-Columbia, August 16, 1984.

2/ "Development of New Crops: Needs, Procedures, Strategies, and Options." CAST, Council for Agricultural Science and Technology. Report No. 102. October, 1984.

3/ Knox, E.G., and A.A. Theisen (eds.). 1981. "Feasibility of Introducing New Crops: Production-Marketing-Consumption(PMC) Systems." A report prepared for the National Science Foundation by Soil and Land Use Technology, Columbia, Maryland. Printed by the Rodale Press, Emmaus, Pennsylvania.

Senator ABDNOR. Thank you. Mr. Sampson, we are looking forward to hearing from you.

STATEMENT OF RONALD L. SAMPSON, ASSOCIATE DIRECTOR, PRODUCT DEVELOPMENT DEPARTMENT, INDUSTRIAL CHEMICALS DIVISION, THE PROCTER & GAMBLE CO.

Mr. SAMPSON. Thank you, Senator Abdnor.

The purpose of my testimony is to supplement the CAST report with additional comments from an industrial viewpoint. I speak as an individual scientist and contributor to the CAST study, not as a representative of my employer.

In my prepared statement, I elaborate on the needs and opportunities for new crops. However, I wish to only briefly emphasize two points.

First, it is imperative that new crops be developed with specific, reasonably well defined needs in minds. To merit support, new crop candidates must present plausible means to meet specific needs.

Second, there appear to be many opportunities for development of new crops to meet identifiable needs. Opportunities exist for both new food crops and new industrial crops, that is, crops primarily intended for use as industrial raw materials. Some of these latter needs involve strategic or critical raw materials.

I wish to turn attention to some of the factors which I believe are critical for success in the development of new crops. As described in the CAST report, success in the development of new crops depends on many factors, and the absence of just one factor can deny success. I will touch on a few of the factors involved—and the form in which I discuss them will drift a bit from their presentation in the report.

I have labeled the first of these as the "co-factor" of cooperation with coordination. The CAST report emphasizes that cooperation between organizatons and individuals is needed throughout the development process. This cooperation bridges across government at all levels, academia and industry. It also bridges across scientists, engineers, and other professionals of many disciplines or fields of expertise. I have combined a subtle element of coordination with that of cooperation to specify the concept of a close, genuinely open and mutually supportive, interactive effort, which also is highly organized and efficient.

The second factor I would like to discuss is the "critical massing" of resources in terms of individuals of the needed diverse disciplines to provide synergism-in-action. New crop developments are a multidisciplined task, and the bringing together of all the needed disciplines early in a program can greatly accelerate a program and increase its overall chances for success. Synergism and enthusiasm spring forth from interactions between individuals of different disciplines and perspectives when they are joined together for a common purpose.

Making connections is another important factor. By connections, I mean connections in information, knowledge, and ideas among organizations and individuals. Lack of information connections frequently delays the initiation of new crop programs.

Additionally, there is an element of assessments, in a "checks and balances" sense, included in the term "connections" as I am using it. On an ongoing basis, connections must be made among appropriate resources to enable assessments on the plausibility of a new crop candidate meeting some definable need. Specifically, market, product development, and economic considerations must be linked with botanical prospects to provide a judgment by experts on what may be possible, rather than being limited to what is known to be possible. Making the right kind of connections after a project has been initiated keeps a project on the right track.

The last, and perhaps most surprising, factor I would like to address is that of realistic expectations. Without realistic expectations being established at the onset of any new crops program, it will be almost impossible to maintain the kind of steady support needed to generate success. The two principal issues on expectations deal with the developmental time scales and probabilities of success involved with new crops.

New crop developments take a long time and progress is frequently measured on a scale of decades rather than years. We should hope to accelerate such developments in the future relative to the timetables of the past. However, funding strategies must be based on well-planned programs with budgets that can be supported over the long periods needed to generate results.

Similarly, new crop development programs need to be defined with the understanding that any single new crop venture at an early stage of development has only a low probability of success. As Mr. Knowles mentioned, in industry, development of many new products must be attempted to provide even a single success. The key to overall success is to ensure that the rewards of the successes also justify the failed efforts as well.

Finally, this morning I would like to offer a few comments on a particular new crop development program known as cuphea. This project provides a current example of how new crop programs can begin, and also how diverse organizations with differing interests can work cooperatively together in such ventures.

Cuphea is a wild plant that produces an oilseed of potential value. The oils produced by cuphea have the potential for being used as replacements for certain imported ones of industrial importance. In addition, the oils of cuphea offer prospects for fostering the development of new chemical products and particularly for replacing imported petroleum used to make certain petrochemicals.

The potential value of cuphea oil was first discovered and reported by USDA scientists in about 1960. After 15 years of being ignored, the agronomic prospects of cuphea began to be investigated, first by European scientists, not American ones. After another 5 years, effort also began in the United States.

Today, a domestic new crop development program for cuphea is well established under the joint sponsorship of the Federal Government—through the USDA—a State program—through a State university—and industry—through a trade association. The program is still relatively modest in size, but meaningful research is in progress within USDA and university laboratories.

Funding of the primary university program is equally shared by the three sponsors. Under this concept, each dollar contributed by

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a sponsor buys $3 of research. Although the monetary commitments are not of a major magnitude, they do trigger involvement at a significant level between the three types of organizations. Industry, for example, formed a special technical subcommittee to provide technical liaison with governmental and academic researchers and administrators. Of course, nothing attracts real interest and attention as well as having some of your own money at stake.

Although we are now optimistic on cuphea's prospects, it will be a long time before we know whether or not it can or will be a successful new crop. Furthermore, we cannot be sure how generally applicable the "cuphea model" will be to other new crop ventures under other circumstances. However, regardless of those outcomes. I believe we are providing a learning experience in cuphea which will be generally beneficial to the establishment and implementation of other new crop programs.

Thank you, Senator Abdnor, for providing an opportunity for me to share my thoughts on this subject with you today. Speaking for Mr. Knowles, Mr. Blase, and myself, we would be pleased to address any questions that you may now have.

[The prepared statement of Mr. Sampson follows:]

PREPARED STATEMENT OF RONALD L. SAMPSON

Today the Council for Agricultural Science and Technology (CAST) is issuing a task force study report entitled: "Development of New Crops: Needs, Procedures, Strategies, and Options". The purpose of my testimony is to supplement that report with additional comments from an industrial viewpoint. I offer my remarks as an individual scientist and contributor to the CAST study, not as representative of my employer.

My testimony will focus on the following aspects of the CAST report: (a) the fundamental needs which new crops might serve; (b) the opportunities for new crops to serve those needs - and some of the benefits and issues involved; and (c) some of the factors needed for success in the development of new crops. Finally, I will conclude my remarks with a description of a new crop development program currently in progress. Although the program involved is relatively small and is still in a very early stage of development, it illustrates how such a program can come into being. It also demonstrates that diverse organizations with differing interests can indeed work cooperatively together in the quest for new crops.

A. On the Needs for New Crops . . .

From a commercial viewpoint, consideration of any new development must always begin with a definition of the needs it might satisfy. That is, any new product or technology being developed for commercial purposes must have a clearly defined reason-for-being in terms of meeting a need. It is not enough that the producer wants to make the product and make a profit from it. Without the product meeting some need, there is no customer for it. Without a customer, there can be no profit and therefore no sustained production. As elementary and obvious as this sounds, neglect of this basic consideration is frequently associated with commercial failures. It has also frustrated various attempts at developing and commercializing new crops as well.

In my opinion, there are needs for new crops arising from the basic needs of each: (1) the nation as a whole; (2) the U. S. consumer; (3) industry; and (4) agribusiness, beginning with the U. S. farmer. With Dr. Knowles addressing needs from a biological viewpoint and Dr. Blase, from an economic one, I shall focus on the fundamental and strategic needs of each sector.

1. <u>In its entirety, the nation has multiple needs which conceptually can be addressed by new crops.</u>

a. The nation has a fundamental need to provide a nutritionally balanced, consumer acceptable food supply at reasonable cost.

b. In addition to food, the nation has a need to develop stable sources of supply for raw materials which are considered critical to the country's defense and well-being. Many such materials are of an agricultural origin.

2. <u>As the ultimate user of products, the U. S. consumer may be seen as the primary beneficiary of successful new crop developments.</u>

a. The consumer needs foods which are nutritional, palatable and attractive, and also affordable. As inferred in the CAST report, during the last few decades, health and nutritional considerations have created new food needs and been primary factors promoting dietary changes.

b. With regard to non-food requirements, consumers need affordable products which add to the well-being and enjoyment of life. Many such products - including soaps and some detergents, for example - are made from agricultural materials.

3. Industry, that is non-agricultural industry, also has needs which can be met by new crops. Such industry plays the dual role of being both a customer (for agricultural products) and a producer (of finished or processed products). Industry of course needs reliable, stable sources of supply for both food and non-food raw materials - again at reasonable costs. However, the scope of industrial needs is broad, and it projects well beyond the agricultural materials now used. Natural, renewable sources for materials not readily or acceptably available from synthetic sources are needed, as well as new materials which create new business opportunities.

4. When viewed as a business complex which begins with the farmer, U. S. agribusiness also has diversification needs which can be addressed by new crops. Agriculture in our country is characterized by such high levels of efficiency and productivity that overcapacity and underutilization of the resources available are chronic problems. These problems might be viewed as arising, at least in part, from an overconcentration of production in too few crops. Indeed, in terms of tangible measures, such as dollar value or tonnage, there is a concentration of the output from the U. S. in relatively few food crops - primarily corn, soybeans and wheat. (Of course when I use the term food crops, I am including crops which enter the food chain as animal feed.) This concentration of agricultural production contributes to a situation in which supply and demand seem to be always out of balance. In turn, this chronic imbalance (which most frequently is oversupply) imposes inordinate stresses on the the agricultural sector of the nation and particularly, in very personal terms, on the U. S. farmer.

B. On the Opportunities for New Crops . . .

In principle, the development of new and alternative crops provides a logical and attractive approach to diversify U. S. agriculture and better utilize the agricultural productivity of the nation to meet the needs outlined above. Indeed the CAST report cites many opportunities (of both general and specific natures) for new crops to meet a variety of needs. These opportunities exist for both new food crops and also for new industrial crops - that is, crops primarily intended for use as industrial raw materials.

1. New Food Crops.

Because our nation's agricultural output is largely concentrated in food production, it is natural to first look for opportunities to develop new food crops. Indeed, the most significant new crop success of this century, the soybean, is a food crop. In addition, many other relatively new and successful crops - such as sunflower, safflower, pecan, avocado and kiwi - are also food crops. As evidenced by these agricultural successes, there is a continual demand for new foods which add to the variety and nutrition of our diets. With over five million acres of the crop planted in 1979, the sunflower illustrates that some of these developments can be quite significant. Nevertheless, it is difficult to now foresee another single new crop development of the magnitude of the soybean occurring within our lifetimes. Development and commercialization of the soybean as a major U. S. crop had, in itself, a rather profound impact on the diet of the nation. Soybean oil promoted widescale substitution of margarine for butter and vegetable oils for lard. Meal, the primary product of the soybean, provided a protein source for animal feed that particularly promoted poultry production. However, dietary changes do evolve slowly and, as indicated in the CAST report, there is now evidence that the per capita consumption of food in the United States is actually declining.

Based on dietary trends and the pattern of recent new crop successes, we might therefore expect that, for the foreseeable future, new food crop developments will largely occur in the arena of specialties, rather than commodities. In this context, specialty crops can be viewed as those which are characterized by relatively low levels of production in tonnage terms and relatively high unit values. The kiwi fruit already mentioned presents an example of such a specialty crop success. Introduced into California in 1962, the domestic kiwi now represents about a $25 million industry. Kiwi has undoubtedly been a worthwhile development which is quite important at a local level. Yet, the $25 million industry it inspired is still quite small when compared with that of the soybean, for example, which annually generates well over ten billion dollars in farm income. However, the cumulative effect of many, small successes in new specialty crops can be substantial, and the dietary contributions they make can be quite important.

2. New Industrial Crops

In addition to new food crops, there appears to be immense potential for the development of new industrial crops. The nation's timber industry is, of course, the source of an enormous amount of renewable, industrial raw materials for construction, fiber and chemical products. However, even if we discount timber because it is a product of forestry and not agriculture, domestic industrial crops are still not a new concept. Cotton, for example, is a familiar crop which primarily provides an industrial raw material - fiber for apparel and specialty products. Materials from existing food crops, such as corn and soybeans, are also used in industrial applications - albeit in relatively minor quantities. Nonetheless, in the broad scope of U. S. agriculture, industrial raw materials represent a largely undeveloped area.

The opportunities for new industrial crops might be classified under three primary categories: (a) critical materials; (b) new products; and (c) petroleum replacements.

a. Critical Materials. As you already know, the potential strategic importance of new crops was most recently recognized in the enactment of the Critical Agricultural Materials Act. The existence of this new public law reinforces a point made in the CAST report - that "development of new crops could serve the strategic interests of the country by providing alternative sources for imported raw materials that are not now produced domestically". Some of these materials, such as rubber, castor oil and sperm whale oil, have been classified by prior law as "strategic" materials - that is, materials critical to defense. (The importation of sperm whale oil was of course previously banned by other legislation; thus substitution with alternatives has already been forced.) A vast category of other materials are considered "essential" because they are required by industry to manufacture products for which the nation has day to day dependency. These include a variety of waxes, oils, resins, gums and newsprint.

It seems obvious that our national interests would be served by establishment of domestic sources for critical raw materials. Indeed, because of strategic national priorities, some new crops might well be developed regardless of economic considerations, and then be subsidized by government. However, even for critical materials most new crops will need to be developed and commercialized on their own economic merit. This means that a new domestic crop source for an imported raw material would need to be economically competitive with the imported source to be successfully commercialized.

The benefits to our country of new competitive raw materials supplies are readily apparent. Less obviously, competing overseas suppliers could potentially also realize benefits from U. S. new crop successes. Through agricultural exchange programs, crops developed in the U. S. might be shared with foreign producers as well. In addition, by stabilization of the supply of the material of interest, increased utilization of it would be encouraged, and a larger overall market could result. In general, supply and price volatilities for a commodity discourage new uses from developing and encourage substitution for the uses that already exist. Consequently, a continued erosion of the market for the material results. Supply stabilization through a new annual crop could therefore minimize the permanent market losses which the original foreign suppliers inevitably experience during times of erratic supply and pricing. In net, although a competitive element would be introduced by new crops, the overall market environment and prospects would be improved - even for the foreign producer.

b. New Products. In addition to providing domestic sources of strategic and essential materials, new crops offer prospects for new products of value, particularly in medicines, pesticides, and even herbicides. We live of course in a chemical world. Although man has created a few chemicals that nature never considered, most of the chemicals which surround us (and indeed are us) were in fact creations of nature. Plants contain many complex chemicals which either: (1) cannot be produced synthetically; or (2) cannot be produced as easily and economically as they can be recovered from plant sources. As cited in the CAST report and emphasized by Dr. Knowles, only about three percent of the approximately 300,000 species of higher plants have been evaluated for their potential product value. Statistical probabilities alone suggest that many valuable materials - some perhaps of profound significance to the health of man - are yet to be discovered. However, the technical challenges of finding such materials are akin to looking for a needle in a haystack without knowing what a needle looks like or what it is made of.

In spite of the obstacles, the search for valuable, biologically active substances in the plant kingdom can be rewarding. For example, about one fourth of all prescriptions today contain one or more such chemicals derived from plants. Many other drugs which are now produced synthetically were first identified and evaluated in natural form (from plants). Other new chemicals derived from plants are being evaluated internationally for such important benefits as antitumor (cancer-fighting) activity. Many plant-derived insecticides, such as nicotine, rotenoids and pyrethrum, have been in use for centuries. One of the inviting possibilities of naturally sourced pesticides is the potential for increased safety for humans, animals and the environment. Some of the natural materials may offer more rapid biodegradability, lesser toxicity and greater specificity than synthetic ones.

c. Petroleum Replacements. The development of renewable resources as alternatives to petroleum is not today as popular a theme as it was a few years ago. However, in my opinion there is potential for new crops to reduce our dependency on imported petroleum. Much of the earlier effort to develop agricultural alternatives to petroleum was focused on energy sourcing. With the help of government subsidies, some developments were made in the energy arena - alcohol from corn for gasohol, for example. However, until petroleum prices rise considerably above current levels, it seems unlikely that energy substitutes derived from agriculture will be able to economically compete - on a subsidy free basis - with petroleum. National priorities may of course dictate that development of such energy alternatives should be pursued regardless of current economics. The apparently successful Brazilian experience in developing and promoting use of alcohol as a gasoline replacement provides an example of such an approach. However, development of new crops which provide alternatives to petroleum (or petroleum-derived products), and are also economically competitive without subsidies would obviously be preferred.

In my opinion, prospects for petroleum replacement through new crops do exist; however, they are more likely to be found in chemical product areas than in energy ones. Petrochemicals are simply value-added derivative products of petroleum. Many petrochemicals require a significant amount of processing which starts with chemical building blocks, such as ethylene. (These basic building blocks are rather directly obtained from petroleum or equivalents, such as natural gas.) Obviously, the more processing is involved in making a chemical product from petroleum, the more costly the resulting product will be. A new crop can therefore potentially compete with petroleum if either: (1) it directly produces the desired chemical product; or (2) it produces a chemical which is much closer to the desired final product (and therefore requires less processing). In other words, although it may be difficult for agriculturally derived products to compete directly with petroleum used virtually "as-is", they may well compete with petrochemicals which incur a significant processing cost in their production. Indeed, potential opportunities have been identified for products from new crops to replace certain petrochemicals used in plastics, adhesives, lubricants, synthetic fibers, and detergents. Since the U. S. is a net importer of petroleum, new crop successes which resulted in the displacement of such petrochemicals should have the effect of reducing oil imports.

C. On the Factors for Success in New Crop Development . . .

Although the concept of new crop development to better utilize the agricultural capacity of our nation is an attractive one, in practice the development of new crops has proven to be a frustratingly slow and difficult task. Indeed, new crop development poses immense challenges for those who would undertake it - and even for those who would support it. As described in the CAST report, success in a new crop development venture depends on many factors, and the absence of just one factor can deny that success. My comments will focus on just four general factors which I believe are critical for success: (1) a defined "co-factor" of cooperation with coordination; (2) "critical massing" of resources; (3) connections and a means to make them; and (4) realistic expectations.

1. The "co-factor" of cooperation with coordination, between both organizations and individuals, must be viewed as a very necessary, but not quite sufficient factor for success in new crop developments. (My definition of the "co-factor" combines the two subtly different elements to specify a close, genuinely open and mutually supportive, interactive effort which also is highly organized and efficient.) The CAST report emphasizes that many organizations and functional disciplines must work closely together - virtually throughout the development process. As a crop is developed it moves from being an academic curiosity to a commercial reality. As the program evolves, primary responsibility for the development shifts progressively from academic and governmental institutions to private industry. However, regardless of the development stage and the organization with current primary responsibility, a high level of cooperation with coordination must be achieved between government at all levels, academia and industry. When successes, such as that of sunflower and safflower, have occurred in new crop development, the effective existence of such a "co-factor" between both individuals and organizations was a primary contributor.

2. In addition to the "co-factor" cited above, a "critical mass" of diverse disciplines - including agronomists, botanists, chemists, economists, engineers, horticulturists and many others - must be brought to bear on a new crop development in a timely and collaborative manner. New crop developments are a multi-disciplined task, and the bringing together of all of the needed disciplines early on can greatly accelerate a program and increase its overall chances for success. Synergisms in ideas and action, and also enthusiasm, spring forth from interactions between individuals of different disciplines (and perspectives) joined together for a common purpose. Conversely, the absence of such "critical massing" of disciplines will likely delay, if not prevent, success from being achieved. Obviously, use of the term "critical

mass" here implies combining the minimum amount needed to create the desired effect. Excessive allocations and combinations of resources beyond the critical point are inefficient and can actually be stifling.

3. The factors already cited will help ensure the next factor is realized. Specifically, there must be early and continuing connections made between the needs, opportunities, and prospects for a new crop. There are really two aspects of connections that I have in mind.

The first relates to information flow and awareness. Lack of an organized system to make connections between relevant information, ideas, and resources has been a serious constraint on new crop development efforts. (Unfortunately this type of problem is not confined to the arena of new crops, but is actually rather universal.)

The second aspect relates to assessments. In particular, an early determination must be made that the new crop candidate might plausibly address a well-defined need. Consequently, market and economic considerations must be connected with botanical prospects long before definitive data are available. Expert judgment must be applied to determine what might plausibly be accomplished, rather than being limited to what is known with certainty. Such is the challenge within any research and development program - the need to predict what can be achieved on the basis of limited and very incomplete information. Although failure to make these connections early in a program can result in wasted and futile effort (and disillusionment on the part of the sponsors), care must be made to ensure that an opportunity is not rejected prematurely.

4. Perhaps surprisingly, establishment of realistic expectations may be regarded as an important factor for new crop success. Because new crop development requires the sustained support of many diverse organizations, it is important that realistic expectations be established at the onset of a

program. Unrealistic expectations will inevitably lead to frustration, dissatisfaction and misunderstandings - particularly between the researchers and their sponsors - with a possible consequence that support might prematurely be withdrawn. There are two primary expectations which must reconciled.

First, any single new crop venture at an early stage of development has only a low probability of success. Like other research, new crop development involves doing, or attempting to do, something that has not been done before. Accordingly, it is a risky undertaking and there are more opportunities to fail than succeed. In industry, development of many new products must be attempted to provide even a single success. Similarly, in new crop development more failures than successes must be expected. However, the key to overall success is to ensure that the rewards of the successes are sufficient to justify the failed attempts as well. Fortunately, the past history of agricultural research provides some reassurance in this regard. As cited in the CAST report, annual rates of return to the public on expenditures for agricultural research have been on the order of 50% - a rate that industry would generally find quite enviable.

Second, new crop developments take a long time - even under the most optimistic of circumstances. Such development programs require sustained support for at least ten and more likely twenty years. It is difficult to maintain support for programs which do not yield measurable returns for such a long time. However, without foresighted investment the future will be devoid of new crops and the benefits they can deliver. Although many new national programs seem to be established in an atmosphere of crisis, a crisis is not what new crops need. Programs spawned in a time of crisis realize sudden major infusions of money at spending levels which simply cannot be spent efficiently, and also are not sustainable. Such an approach to new crops would likely lead to frustration and failure because of the long development times involved.

Impatience with high levels of inefficiently spent money showing no immediate results would soon cause withdrawal of support. Consequently, new crops funding must be based on a non-crisis program defined in an orderly manner with efficiency and productivity in mind. Sustained, steady funding - perhaps with programmed growth at a modest rate - must be allocated with the understanding that results can be measured only within very long timeframes.

D. On an Illustrative Example of New Crops Cooperation In Action . . .

A case history example of how a new crop development program can begin, and how a highly cooperative effort can be achieved, can be found in a program currently underway. Specifically, a coordinated effort is in progress to develop and assess the potential for Cuphea, a prospective new crop. Although Cuphea is in a very early stage of technical development and the program related to it is quite modest in size, the support and planning organization for it is fairly well developed. In fact, the organizational aspects of the program provide the primary reason to discuss it at this time. However, some background on the plant itself, and why it is of interest, may be useful for developing an understanding of how and why the program came to be as it is now.

1. Background

Cuphea is a wild plant which is indigenous to the Americas. The plant family of Cuphea has nearly 300 species which are found in a variety of habitats. Although some species have been found in the southern United States as well, it is primarily found in Central and South America. The plant yields oilseeds which are remarkable in two respects.

First, the oil incorporates medium or mid-chain fatty acids, such as the lauric acid found in coconut oil. (Medium or mid-chain fatty acids may be considered as those which have chains of from 8 to 14 carbon atoms, with lauric acid specifically having 12 carbon atoms. Additional information on them is included in the CAST report.) Typical oil seeds, such as soybean or sunflower, are comprised of longer chain fatty acids, such as oleic and linoleic, which have much different physical properties.

Second, the composition of the oil from the different species of Cuphea varies considerably and, in many instances, is remarkably specific. By specific, I mean that in some cases over 90% of the fatty acids contained in the oil are of a single, specific type.

Cuphea has been cited in various literature sources as a potential domestic source of lauric oils - that is, imported oils such as coconut or palm kernel. In reality, Cuphea is potentially much more than that. The medium chain fatty acids that are produced by Cuphea also offer significant potential for replacing certain petrochemicals and fostering the development of new chemical products. Coconut and palm kernel oils, the primary commercial sources of natural fatty acids in this range, are efficient sources of only lauric acids - with the other medium chain varieties present in only relatively minor amounts. Today there are no efficient, natural supply sources for varieties of mid-chain fatty acids other than lauric; however, there are identifiable, potential uses for them. Accordingly, as an annual crop Cuphea could be expected to significantly expand the market for such oils well beyond that which currently exists.

2. The History of Cuphea's Development

As already mentioned, Cuphea is starting out as a wild plant which requires domestication. Of the three avenues to development of a new crop outlined in the CAST report and cited by Dr. Knowles, domestication of a wild species presents the greatest challenge and takes the longest time. Even the mere initiation of work on a wild plant candidate for a new crop has historically taken a long time. This is because an organized or systematic means has not existed to make the needed connections between the crop candidate's prospects and the needs it might serve.

Cuphea was no exception to this pattern since about 15 years passed between the time it was "discovered", and the time the initial connection was made. Although Cuphea was a previously known and somewhat classified plant, the potential value of it remained unknown until the USDA discovered and reported it. Specifically, Cuphea was assessed under the USDA exploratory and screening program which began in 1957. Initial publication of the composition of oils produced by Cuphea was made by USDA researchers in about 1960. However, it was not until 1975 that an initial connection was made and exploratory new crop research was initiated. With a bit of chagrin, I note that in spite of its "discovery" by the USDA, the initial research on Cuphea was not just started late. It was also started in Europe instead of the United States. Initial agronomic research began in a West German university under the sponsorship of European industry who first took note of the USDA reports. It actually took another five years for the Cuphea connection to be made in the United States.

In a very modest way, government and industry cooperation on Cuphea began in 1981. At that time, collections of germplasm were assembled and used to support some initial, exploratory research work in USDA laboratories. In 1982, a cooperative connection was made between the German and U. S. work. As a result, a visiting German researcher, who previously had been working on Cuphea in his native country, began preliminary work at a university in the United States. In 1983, his work was integrated into a formalized program at Oregon State University. Under the joint sponsorship of the USDA, the State of Oregon, and industry, the effort at Oregon was structured to be a primary part of the overall program to develop and assess the new crop potential for Cuphea. During 1984, both the program at Oregon State and the direct USDA research effort on Cuphea were significantly expanded. Work on Cuphea was also initiated, to a lesser degree, at several other universities across the country.

The cooperative organization and relationships established to support the work at Oregon State warrant some additional comment because of the examples they provide. Under the funding concept being applied there, the Federal government (through the USDA budget), the State of Oregon (through the university budget), and industry (through voluntary contributions via a trade association group) each contribute matching amounts of support. In other words under this program, each sponsoring organization buys three dollars of research for each dollar it contributes. The concept is of course attractive to each sponsor because it buys not only more research for the money, but it also promotes the cooperative involvement and participation needed between government, academia and industry. (Nothing promotes real interest and attention as well as having some of your own money at stake.) In the case of Cuphea, the industry trade association also formed a special technical subcommittee to provide technical liaison with academic and governmental researchers and administrators.

In spite of its successful initiation in the Cuphea program, such a cooperative support approach may not be universally workable because of the following considerations.

First, a high level of cooperation has been possible for Cuphea because at the onset industry took the position that Cuphea was properly a non-proprietary, open project which should remain in the public domain. This enabled a high level of open collaboration between governmental agencies, universities and industrial companies that simply would not be possible if proprietary interests were involved. Although similar situations may exist for other new crop development programs, not many situations are likely to be found wherein the market potential and commercial interests for a new crop product are so clearly defined, yet proprietary posturing is not involved.

Second, there are practical limitations on the amount of funding which can be generated from industry on an equal parts basis. Because of the very long term, speculative nature of such programs, any individual company will be reluctant to commit a great deal of money to it. In addition there will be an inherent reluctance on the part of industry to provide major infusions of funds since industry will be a customer for, rather than producer of, a new crop such as Cuphea. As suggested earlier, agribusiness, and particularly the U. S. farmer, might be seen as the most direct beneficiaries of a successful new crop development program.

In my opinion, the considerations cited above suggest the following: (a) formation of industry sponsorship groups does provide a useful approach to generate meaningful sums of money while holding individual company contributions at a sustainable level; and, (b) on behalf of the U. S. farmers, consumers and overall national interests, government funding must play a major role in a new crop development program - at least until commercialization is in sight and industry, particularly agribusiness, can assume responsibility on its own.

With an annual budget of about $300,000, the Cuphea program at Oregon State is still relatively modest in size. Although this is a great deal of money for us as individuals, on the scale of government research expenditures it is small indeed. Nonetheless, such an amount of money can provide a meaningful start for a long term and speculative venture such as Cuphea. It can serve as a focal point for gathering the needed "critical mass" of researchers together. The momentum, stimulation and enthusiasm which can be created by such sums of "seed money", so to speak, can be significant. In the case of Cuphea, we won't know whether or not it can or will become a successful new crop for a long time. However, the start made in the program by the approach described above provides a basis for optimism. Hopefully, it will also provide some contemporaneous learning which might be useful in the initiation of other new crop programs as well.

Senator ABDNOR. I think we'll go ahead with the remaining witnesses.

I would like to introduce you gentlemen to Senator Symms, who's a member of this committee. Senator Symms and myself are two of the very few people actually interested in farmers, maybe more over here on the Senate side, but Senator Symms has a fruit orchard in Idaho and I know is always interested in new possibilities. I'm an old grain farmer in South Dakota who has wheat, so the two of us find your testimony interesting.

But there is another side that we are going to go into as I said earlier. I am going to have to go to a committee, I am chairman. It deals with another subject that is going to be on the floor very soon. I hate to have to leave but I know you are in good hands with Senator Symms. He is very interested in this, so I will turn this over to you.

Senator SYMMS [presiding]. Thank you very much, Senator, and gentlemen, I appreciate your testimony. As Senator Abdnor has pointed out, I think it is fascinating. I compliment you for this booklet that we have here this morning.

I might ask one question. Is this published once a month, it says October 1984, or is this a one-time report?

Mr. BLACK. That is just a one-time report.

Senator SYMMS. Let us go ahead and we may have a few questions here, but we will hear from Mr. Robert Fraley, manager of the biotechnology program at Monsanto.

STATEMENT OF ROBERT T. FRALEY, MONSANTO CO., ST. LOUIS, MO

Mr. FRALEY. Again, I would like to thank you for the opportunity of presenting my paper this morning. The title of my paper is "New Directions for Agriculture: Potential Impact of Biotechnology". This title is somewhat misleading because it implies that the applications of biotechnology lie in the future when in fact biotechnology has already had a major impact on agriculture.

Biotechnology refers to the use of living cells or their isolated components for industrial applications. It encompasses a wide range of methods, including plant breeding, cell and tissue culture, cell fusion, fermentation, and embryo transfer, which have been developed from basic research in the fields of genetics, biochemistry, microbiology, immunology, physiology, reproductive biology, and cell biology. New techniques such as production of monoclonal antibodies and recombinant DNA manipulations are becoming extensively used in various of biotechnological research.

It is important to emphasize that these new techniques augment and extend other technological methods. For example, the methods of embryo transfer and genetic engineering will accelerate and extend traditional plant and animal breeding approaches.

Again, let me emphasize that biotechnology is not new to plant and animal agriculture. The application of genetic research to plant breeding and animal husbandry has been a major contributor to the remarkable development of American agriculture. During the last decades, biotechnology has had an increasing impact on agriculture as well as the related chemcial and food processing industries. For example, antibiotics, amino acids and other supplements produced by fermentation technology and routinely added to feeds to stimulate animal growth and prevent disease. Microbial seed inoculums and agrichemicals, including fertilizers, herbicides, plant growth regulators, pesticides, are commonly used to increase crop productivity. Immobilized cells and enzymes are being used to catalyze biochemical conversions in the production of several specialty chemicals and feedstocks.

Within the last decade, major advances have been made in two important areas of biological research. The first is the understanding of gene function and architecture at the molecular level. Powerful new methods have been developed for identifying, isolating and joining specific DNA segments as well as determining and modifying their DNA sequence. These methods, which provide the basis for recombinant DNA technology, have been used for several years to manipulate genes in bacteria and produce rare and valuable proteins. It will soon be possible to use these technologies to introduce specific genes or combinations of genes both into crop plants and livestock to increase their agricultural productivity.

A second area of major advance has been the understanding of the immune response and antibody production. Techniques have been established for the identification and isolation of regulatory factors and proteins which modulate various immune responses. Powerful methods have been developed for producing large quantities of identical or monoclonal antibodies, which because of their unique homogeneity and specificity, have proven to be exceedingly useful reagents in protein purification, chemical and biological assays, diagnostics, and disease treatment.

The potential for using recombinant DNA manipulations and monoclonal antibodies in conjunction with other biotechnological methods for improving agricultural productivity is enormous.

I would first like to discuss some applications to animal agriculture. Growth in United States and world population, together with increased consumer buying power will increase world demand for animal protein from 574 to 953 billion millicalories between the year 1970 and the year 2000. In view of the increasing competition for agricultural resources by nonagricultural sectors, this demand can be best met by increasing livestock productivity. It is estimated that fertility, health, and nutrition problems combine to reduce livestock productivity by 30 to 40 percent.

The potential applications of biotechnology for increasing productivity in animal agriculture include:

The area of disease prevention and treatment where immunological detection and treatment of livestock diseases will be substantially improved by development of monoclonal antibodies to infectious virus, bacteria, and parasites. An immunological product currently on the market is a monoclonal antibody based passive immunization preparation which prevents. "scours" in cattle. Vaccines produced by recombinant DNA methods have received considerable attention for prevention of diseases in livestock. Currently vaccines against several animal diseases, including foot-and-mouth disease and swine dysentery, are being tested in animal trials.

A second area of impact will be in animal growth promotion and nutrition. Hormones and peptides which regulate specific physiological processes have been extensively investigated. Classes of animal growth hormones have been identified which increase feed efficiency and stimulate lactation, and may lead to increased growth, improved lean-to-fat ratios and milk production. Extraction from pituitary glands did not provide these animal growth hormones in sufficient quantities for commercial use. The availability, however, of genetic engineering methods to produce large quantities of animal growth hormones by fermentation technology has allowed then commercialization, and these efforts are currently underway by several U.S. companies. The preliminary results are quite promising in that the administration of growth hormones has been shown to result in 10- to 15-percent increase in both carcass weight and milk production.

A final area in which genetic engineering will stimulate productivity in animal agriculture is increasing reproduction efficiency. Improved methods for synchronization of estrus, collection of ova, embryo storage, and embryo implantation have increased the use of embryo transfer in the breeding of livestock, particularly dairy cattle. These methods have contributed to the doubling of average milk yield of cows in the United States over the last 30 years. Advances in animal reproductive biology and the potential for using recombinant DNA technology for large-scale production of reproductive hormones and other peptides which are effective in synchronizing estrus or stimulating superovulation should extend the use of embryo transfer to other animals. Another impact of biotechnology will be the use of monoclonal antibodies in embryo sexing. Sex control would have a major effect on the beef, pork, and poultry industries since males wean more heavily and gain weight more efficiently than females.

An area which has been somewhat controversial has been the potential for using genetic engineering and biotechnology methods for genetic modification.

The feasibility to using biotechnological methods to directly modify animals has already been demonstrated for laboratory mice. These procedures, which involve the injection of foreign genes directly into fertilized eggs with small microcapillary needles followed by transplantation of the injected eggs into a surrogate mother, can in principle, be applied to animal breeding programs. Although the methods for embryo transfer in cattle are well established, the application of such gene transfer methods to animal agriculture for increasing disease resistance and growth will require a more detailed understanding of gene structure and regulation as well as improvements in embryo culture technology. It should be emphasized that the targets for genetic engineering will be the same for those traditional animal breeding programs; however, the newer technology will facilitate faster genetic improvement.

I would now like to discuss the applications of biotechnology to plant agriculture. Methods such as cell culture, plant regeneration, cell fusion, and recombinant DNA manipulations will have a major impact on plant agriculture.

The first area I would like to discuss is that of microbial inoculums. Rhizobium seed inoculums are widely used to improve nitrogen fixation by certain legume crops. Extensive study of the structure and regulation of the genes involved in bacterial nitrogen fixation will likely lead to the development of more efficient inoculums. Research on other plant colonizing microbes has led to a much clearer understanding of their role in plant nutrition, growth stimulation, and disease prevention and the possibility exists for their modification and use as seed inoculums.

The second area for impact I would like to discuss is that of plant propagation. Cell culture methods for regeneration of intact plants from single cells or tissue explants have been developed and are used routinely for the propagation of several vegetable, ornamental, and tree species. These methods have been used to provide large numbers of genetically identical, disease-free plants which often exhibit superior growth and uniformity over conventional seed grown plants. Such technology holds promise for important forest species whose long sexual cycles reduce the impact of traditional breeding approaches.

The final area I would like to discuss is the genetic modification of plants. Three major biotechnological approaches: Cell culture selection, plant breeding, and genetic engineering are likely to have a major impact on the production of new plant varieties. The targets for crop improvement via biotechnology manipulations are essentially the same as those of traditional breeding approaches, that is, to increase yield, improve qualitative traits, reduce labor and production costs. However, the newer technology offers the potential to accelerate the rate and type of improvements beyond that possible by traditional breeding. Of the various biotechnological methods being used in crop improvement, plant genetic engineering is the least established, but is the most likely to have a major impact on crop improvement. Using gene transfer techniques, it is possible to introduce genes from one plant species into another. For example, it has been possible to introduce storage protein genes from French bean into tobacco plants. It has been possible to introduce genes essential for the photosynthetic process from pea plants into petunia plants. By eliminating sexual barriers to gene transfer, genetic engineering will greatly increase the genetic diversity available to plant breeders for crop improvements.

I would like to conclude by pointing out that the application of biotechnological methods is expected to significantly increase agricultural productivity by the year 2000. Biotechnology will have direct impact on several industries, including the seed and animal production industries, the chemical, pharmaceutical, and food processing industries. Biotechnology will also have a major impact on the consumer. Agricultural products will be available with greater nutritional value, higher quality, greater safety, and at lower cost.

It is important to consider that, while recombinant DNA techniques and other biotechnological methods are very powerful research tools, their efficacious utilization for plant and animal improvement requires a precise molecular understanding of cell structure, function, and regulation. Except for a few products currently under development, the successful application of biotechnology for solving problems in plant and animal agriculture will be dependent on greatly increased knowledge of the physiological, biochemical, and immunological processes and no specific technical breakthroughs in cell manipulation and culture, gene identification, protein purification, and gene transfer methods. Increased research funding in the life sciences and agricultural areas would significantly accelerate the rate of progress in biotechnology and help ensure the future availability of an adequate supply of highly trained students and young scientists. It will also be essenial that existing governmental agencies, the National Institutes of Health Recombinant DNA Advisory Committee, EPA, and USDA establish guidelines which address health and environmental safety issues and which allow the United States to maintain its position as a worldwide agricultural leader.

Technological innovations in biotechnology have historically contributed to the increasing productivity of American agriculture. The development of the powerful new technologies I have discussed this morning promise that this trend will continue in the future.

Thank you.

[The prepared statement of Mr. Fraley follows:]

Prepared Statement of Robert T. Fraley

NEW DIRECTIONS FOR AGRICULTURE: POTENTIAL IMPACT OF BIOTECHNOLOGY

I. INTRODUCTION

Definition--Biotechnology refers to the use of living cells or their isolated components for industrial applications. It encompasses a wide range of methods including plant breeding, cell and tissue culture, cell fusion, fermentation and embryo transfer, which have been developed from research in the fields of genetics, biochemistry, microbiology, immunology, physiology, reproductive biology and cell biology. Newer techniques such as production of monoclonal antibodies and recombinant DNA manipulations (discussed below) are becoming extensively utilized in various types of biotechnological research.

Background--Biotechnology is not new to plant and animal agriculture; the application of genetic research to plant breeding and animal husbandry has been a major contributor to the remarkable development of American agriculture. During the last several decades, biotechnology has had increasing impact on agriculture as well as the related chemical and food processing industries. For example, antibiotics, amino acids and other supplements produced by fermentation technology are routinely added to feeds to stimulate animal growth and prevent disease. Microbial seed inoculums and agrichemicals (fertilizers, herbicides, plant growth regulators, pesticides, etc.) are commonly used to increase crop productivity. Immobilized cells and enzymes are being used to catalyze biochemical conversions in the production of several specialty chemicals and feedstocks.

Within the last decade, major advances have been made in two important areas of biological research:

1) The understanding of gene function and architecture at the molecular level. Powerful methods have been developed for identifying, isolating and joining specific DNA segments as well as for determining and modifying their DNA nucleotide sequence. These methods, which provide the basis for recombinant DNA technology, have been used for several years for manipulating genes and producing valuable proteins in microorganisms such as bacteria and yeast. Only recently have techniques been developed for genetically modifying higher eukaryotic cells; within the last two years intact mice (Palmiter *et al.* 1982), fruit flies (Spradling and Rubin 1982) and plants (Horsch *et al.* 1984) been produced which contain and express foreign genes. It will soon become technically possible to introduce a specific gene or combinations of genes into both crop plants and livestock to increase their agricultural productivity.

2) The understanding of immune system regulation and antibody production. Techniques have been established for the identification and isolation of regulatory factors and proteins which modulate various immune responses. Powerful methods have been developed for producing large quantities of identical (monoclonal) antibodies (Kohler and Milstein, 1976). Because of their unique homogeneity and specificity, monoclonal antibodies have proven to be useful reagents in protein purification, chemical and biological assays, diagnostics, and disease treatment.

II. COMMERCIAL APPLICATIONS

The potential for using recombinant DNA manipulations and monoclonal antibodies in conjunction with other biotechnological methods for improving agricultural productivity is enormous. Commercial applications of biotechnology will impact several key areas in plant and animal agriculture:

Animal Agriculture--Growth in U.S. and world population, together with increased consumer buying power will increase world demand for animal protein from 574 to 953 billion Mcal between 1970 and the year 2000 (Hansel, 1985). In view of the increasing competition for agricultural resources (land, products etc) by nonagricultural sectors, this demand can be best met by increasing livestock productivity. It is estimated that fertility, health and nutrition problems combine to reduce livestock productivity by 30-40%. The potential applications of biotechnology for increasing productivity in animal agriculture include:

- Disease prevention and treatment. Immunological detection and treatment of livestock diseases will be substantially improved by development of monoclonal antibodies to infectious virus, bacteria and parasites. Similar diagnostic tests are already available for detection of human diseases, but will require more cost-effective production for application to animal agriculture. Other diagnostic methods based on DNA or RNA hybridization may also be important. An immunological product currently on the market is a monoclonal antibody based passive immunization preparation which prevents "scours" in calves. Vaccines produced by recombinant DNA methods have received considerable attention for prevention of diseases in livestock. Currently, vaccines against several animal diseases including foot-and-mouth disease and swine dysentery are being tested in animal trials (OTA-BA-218).

- Growth promotion and nutrition. Hormones and peptides which regulate specific physiological processes have been extensively investigated. The identification of classes of animal growth hormones which increase feed efficiency and stimulate lactation may lead to increased growth, to lean-to-fat ratios and/or milk production (Pell, *et al.* 1981). Efforts to commercialize such animal growth hormones are currently underway by several U.S. companies. The production of feed additives (vitamins, amino acids, etc.) by fermentation technology using biotechnology-derived microbes will also have substantial impact on animal nutrition.

- Reproduction Efficiency. Improved methods for synchronization of estrus, collection of ova, embryo storage and embryo implantation have increased the use of embryo transfer in the breeding of livestock, particularly dairy cattle. These methods have contributed to the doubling of average milk yield of cows in the U.S. over the last 30 years. Advances in reproductive biology and the potential for using recombinant DNA technology for large scale production of reproductive hormones and peptides which are more effective in synchronizing estrus or stimulating superovulation should extend the use of embryo transfer to other animals. A major impact of biotechnology will be the use of monoclonal antibodies in embryo sexing. Sex control would have a dramatic effect on the beef, pork and poultry industries (males wean heavier and/or gain more efficiently) as well as the dairy industry.

- Genetic modification. The feasibility of using biotechnological methods to directly modify animals has already been demonstrated for laboratory mice (Palmiter *et al.* 1982). These procedures, which involve the injection of foreign genes directly into fertilized eggs with small microcapillary needles followed by transplantation of the injected eggs into a surrogate mother, can in principle, be applied to animal breeding programs. Although the methods for embryo transfer in cattle are well established; the application of such gene transfer methods to animal agriculture for increasing disease resistance and growth will require a more detailed understanding of eukaryotic gene structure and regulation as well as improvements in embryo culture. The targets for genetic engineering will be the same as those in traditional animal breeding programs; however the newer technology will facilitate faster genetic improvement.

Plant Agriculture--The application of biotechnological methods such as cell culture, plant regeneration, cell fusion and recombinant DNA manipulations will also have a major impact on plant agriculture. While the impact of biotechnology on plant agriculture will lag behind its more immediate impact on animal agriculture, its long-range effect could be even more substantial. The potential applications of biotechnology on plant agriculture include:

- Microbial inoculums. Rhizobium seed inoculums are widely used to improve nitrogen fixation by certain legumes. Extensive study of the structure and regulation of the genes involved in bacterial nitrogen fixation will likely lead to the development of more efficient inoculums. Research on other plant colonizing microbes has led to a much clearer understanding of their role in plant nutrition, growth stimulation and disease prevention and the possibility exists for their modification and use as seed inoculums. The use of microbially produced pesticides such as *Bacillus thuringiensis* spore preparations, Baculoviruses and certain fungal insecticides has met with increasing acceptance and commercial success (Miller *et al.* 1983). The production of more potent or more broadly applicable microbial pesticides by biotechnological approaches seems likely.

- Plant propagation. Cell culture methods for regeneration of intact plants from single cells or tissue explants have been developed and are used routinely for the propagation for several vegetable, ornamental, and tree species (Murashige, 1974; Vasil *et al.* 1979). These methods have been used to provide large numbers of genetically identical, disease-free plants which often exhibit superior growth and uniformity over conventionally seed grown plants. Such technology holds promise for important forest species whose long sexual cycles reduce the impact of traditional breeding approaches. Somatic embryos produced in large quantities by cell culture methods can be encapsulated to create artificial seeds which may have advantages for propagation of certain crop species.

- Genetic modification. Three major biotechnological approaches: cell culture selection, plant breeding (both traditional and newer approaches such as haploid production, use of embryo rescue, irradiated pollen etc.) and genetic engineering are likely to have a major impact on the production of new plant varieties. The targets for crop improvement via biotechnology manipulations are essentially the same as those of traditional breeding approaches; (increased yield, improved qualitative traits, reduced labor and production costs) however, the newer technology offers the potential to accelerate the rate and type of improvements beyond that possible by traditional breeding. Of the various biotechnological methods that are being used in crop improvement, plant genetic engineering is the least established, but is the most likely to have a major impact on crop improvement. Using gene transfer techniques, it is possible to introduce DNA from one plant into another plant, regardless of normal species and sexual barriers. For example it has been possible to introduce storage protein genes from French bean into tobacco plants (Murai *et al.* 1983) and to introduce genes encoding photosynthetic proteins from pea into petunia plants (Broglie *et al.* 1984). The transformation technology is not limited just to the transfer of plant genes; DNA coding sequences from virtually any source can be introduced into plants providing they are engineered with the appropriate plant gene regulatory signals. Several bacterial genes have now been modified and shown to function in plants (Fraley *et al.* 1983; Herrera-Estrella, *et al.* 1983). By eliminating sexual barriers to gene transfer, genetic engineering will greatly increase the genetic diversity available in plants.

III. CONCLUSION

The application of biotechnological methods is expected to significantly increase agricultural productivity by the year 2000. Biotechnology will have direct impact on industry (seed production, chemical, pharmaceutical, food processing etc.) and on the consumer (agricultural products with greater nutritional value, higher quality and safety, lower cost etc.).

It is important to consider that, while recombinant DNA techniques and other biotechnological methods are very powerful research tools, their efficacious utilization for plant and animal improvement requires a precise molecular understanding of cell structure, function and regulation. Except for a few products currently under development, the successful application of biotechnology for solving problems in plant and animal agriculture will be dependent on greatly increased knowledge of physiological, biochemical and immunological processes and on specific technical breakthroughs in cell manipulation and culture, gene identification, protein purification and gene transfer methods. Increased research funding in the life sciences and agricultural areas would significantly accelerate the rate of progress in biotechnology and help ensure the future availability of an adequate supply of highly trained students and young scientists. It will also be essential that existing governmental agencies (NIH Recombinant DNA Advisory Committee, EPA and USDA) establish guidelines which address health and environmental safety issues and which allow the U.S. to maintain its position as a worldwide agricultural leader.

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Senator SYMMS. Thank you very much, Mr. Fraley, for what I would have to say I is exciting testimony before the committee here this morning. I appreciate it very much.

We will next hear from Mr. Robert Lanphier III, chairman of the board of Dickey-john Corp. In Auburn, IL.

STATEMENT OF ROBERT C. LANPHIER III, PRESIDENT, DICKEY-JOHN CORP., AUBURN, IL

Mr. LANPHIER. Good morning. Senator Symms, I would ask that my prepared statement be made a part of the record.

Sentor SYMMS. I would ask unanimous consent that all statements will be included in the record in total. Please go right ahead.

Mr. LANPHIER. For these that might not be familiar with Dickey-john, the other two people here from Monsanto and Procter & Gamble may be a little better known Dickey-john is in the agriculture business and we are the leader in supplying instrumentation for farm equipment and for measuring the quality of farm products.

American agriculture is today the most dynamic, the highest technology industry in the world. There are few, if any, technologies that are not already or now in the process of being assimilated into the agricultural industry.

The productive capacity of American agriculture is a clear reflection of the research and educational system the U.S. Congress had the wisdom and foresight to enact in 1862 and has continued to support ever since.

As long as there are people on Earth that are without adequate, nutritional, high quality food available at reasonable costs, as long as we must contend with pests, droughts, and other adverse conditions, as long as we are degrading our soil and environment and are depleting our water and other natural resources, the need for continuing research and the assimilation of new technologies will exist. We must have the wisdom and the foresight today to be able to meet these continuing challenges of tomorrow.

There are three clearcut tasks for agriculture. One, the American consumer expects food to be of high value. Two, this country must maintain its gobal competitiveness in grain and other food products. Three, we must reduce our consumption of nonreplenishable resources.

Continuing research, innovation, new technologies, and the successful assimilation of these technologies will be some of the major factors directly related to meeting these tasks.

Another factor is the farm policy which directly addresses these tasks. The 1985 farm bill will determine whether these two factors operate in concert or in conflict.

The needs of the farmer have not changed for several thousand years and probably will not change for centuries to come. It is only the level of the sophistication in the ways which these needs are met which constantly changes.

There are certain basic functions such as tilling the soil, adding nutrients to the soil, planting the seed, cultivating, harvesting, and storing the crop which are as prevalent in the earliest recorded history of man as they are today.

One technology, an electronic instrumentation, with which I have some familiarity, is providing farmers with an improved management information system in order to farm more productively and more knowledgeable. Today, electronic instrumentation is improving tractor efficiency, reducing soil compaction, reducing tire and equipment wear, and assuring uniform tillage practices.

Through instrumentation, we can carefully control and maintain a uniform application rate as we apply nitrogen, potassium, and phosphate which are in fertilizers, liquid chemicals, gaseous, and hydrous ammonia injection. We can even go a step further and vary the rate of application of these nutrients depending on the need of each unit area of field for which we have a soil composition analysis. As yet we do not have a soil analyzer or sensor to provide a continuous measurement of soil. When we do, the application rate will be automatically varied to give uniform field fertility. This will be a very real challenge with significant economic justification.

As we are able to obtain more data on the nutrient quality of soil, we can use this information in regulating the optimum distribution of planting seed.

Electronic instrumentation has been commercially available for several years, permitting the automatic changing of the planting rate as the farmer perceived change was needed.

As we develop the sensing technology along with better distribution systems, we will be able to optimize the use of our existing water reserves and also to bring into production land which today cannot be farmed due to a water reserve that with today's methods would be quickly depleted.

Modern chemicals are helping to protect crops against pests, fungi, and weeds, but the rate of application should be dependent upon a unit area's intensity of infestation. Chemicals could be applied more precisely, more accurately, if more information were available, a condition which would only improve the quality of our air, water, and soil.

Today, electronic instrumentation can assure uniform application of chemicals. Tomorrow, our farm information system may receive data on the early presence of pests by satellite infrared detection, along with instructions on the type of chemical, the application rate by unit area, and the recommended time of application based on long-range weather forecasts.

Today, we are still missing a few of the sensing devices.

With accurate implementation for determining the position in a field, we will then be able to know for any given unit area the soil composition. We will apply only the necessary nutrients. We will plant the optimum seed population based on the new level of fertilization. We will apply the most economic chemicals or friendly predators and we will know the yield of a crop in each unit area, information which will give us a new data base or add to a continuing, growing data base for the planning and the managing of the next year's production.

Electronic instrumentation has proven by far the best means of measuring the temperature of grain throughout a storage bin where increases in temperature can be an early indication of bacteriological activity. We still have much to learn in effectively and economically detecting potential degradation and depletion in crop storage.

Today, virtually every new plant is purchased with a seed monitoring system. Cotton harvesters have a monitoring system. Grain combines are monitored for early detection of problems as well as the amount of grain lost after threshing. Sprayers and spreaders have closed-loop control systems to assure uniform application of chemicals. Tractors and combines have, as a minimum, electronic digital tachs, with more sophisticated information systems coming on the market with the introduction of each new model. Today, many farm equipment dealers, and even some farmers, feel comfortable replacing sensor or a plug-in circuit board or even troubleshooting a system to locate a troublesome intermittent.

As we move into other facets of agriculture, instrumentation has long provided a means for measuring the moisture content in grains and forages, and more recently can do rapid analysis of protein, oil, fibre, and starch using near infrared techniques. Today, instrumentation is used for measuring protein, butterfat, lactose, and water in milk, for counting the somatic cells in milk for mastitis detection. Instrumentation is used for rapidly measuring the fat or lean content of ground meat. Electronics are being routinely used to minimize waste, improve safety, and permit cost-effective yields by reducing input costs.

In the near future, diagnostic instrumentation will detect farm equipment problems at their inception and inform the operator through a visual display or vocally as to the seriousness, the corrective action, and the repair procedures. It might tell him the nearest dealer stocking that part and reserve that part in the dealer's inventory before the operator has time to even stop the machine.

The quality of agricultural output will be monitored, identified from producer to the supermarket. Milk will be graded by butterfat and protein by cow at the farm at the time of milking. Nonintrusive methods of fat protein analysis of live animals will improve feeding programs at an excellent savings once automatically controlled feed formulation systems are in place.

Yes, electronic instrumentation is a new era in agriculture. Just as this and other technologies have combined with the great American system of capitalism and private enterprise, with the entrepreneurial spirit of the farmer and with our great national resources to make American agriculture the most productive in the world. Together, they will continue to give America the world's greatest ability for providing the world's most needed commodity and at the same time sharing, exporting our new innovations, and knowledge to reduce starvation and malnutrition throughout the world.

Agribusiness is taking a much greater interest in public policy after their severe recession of the past few years. Such recessionary problems result in: (1) reduction of investment in corporate research; (2) reduction of funding and grants to research institutions; (3) delay of introduction of new technologies and new products; (4) reduction of participation and funding of technical societies in areas such as where industry standards are established; and (5) slowing of acquisition of new ideas.

Research must go beyond today's needs or even those needs we can anticipate for tomorrow. Research must make a wealth of technologies available. When we will adopt these technologies will be determined by the marketplace. The marketplace may be driven by economic forces, run by regulatory or legislative requirements, or merely by customer demand. Technology cannot anticipate the needs of the marketplace, and though the marketplace may put priority on certain types of research, the marketplace cannot wait for technology when the need arises. Research must give us an excess of technologies upon which to draw.

In conclusion, I would like to share some of my views as an agribusiness executive on farm policy and technology.

First, we must work for a positive farm policy. This will only occur when the administration and the Congress have a clear perspective as to how the people of the United States feel about the role of agriculture in our Nation's future. What do the people of this country want, and what are they willing to pay, not what do special interest groups want and how much are they willing to demand. We must address, as separate issues, an agricultural policy relative to economic and sustainable farm production units which can meet our domestic and international food requirements, versus a rural policy for small farms which cannot compete. Such an approach could well result in eliminating unworkable commodity programs and, instead, instigate income supplement programs that reflect the need to deal with the socioeconomic needs of Americans living on farms in rural America.

Second, the administration, the Congress, our Governors, and our land grant colleges must put aside pork barrel goodies, special interests, good 'ole Charlies, and reinventing the wheel except for instructional purposes. They must utilize cooperative, multidisciplinary approaches in place of both inter- and intra-duplication of disciplines. They must determine how we can most effectively utilize the billions of dollars we have available to continue an outstanding agricultural education system and to fund the thousands of highly dedicated researchers. There is a concern not enough bright young minds are coming into agriculture, an industry that utilizes virtually every high-technology discipline.

With the same determination, we must clearly identify our public funded research efforts for preserving our soil, water, and other natural resources, for protecting our air and water environments and for improving the nutrition of our people. We must adequately monitor public funded research versus private funded research, and higher risk basic research versus applied research.

Let us not forget what the September 1983 CAST report stated so well: "Additional farm income will not come out of marketing margins, but will come from taxpayers, consumers, or improved farmer efficiency. Investments in research and extension to improve farming technology, management, and marketing contribute to efficiency gains, and benefit the whole population more than they benefit farmers."

And third, we need strong direction and prioritization of all of these efforts. The 1981 farm bill established the Office of Assistant Secretary of Science and Education, which, for the first time, consolidated under one authority all of the various parts of our educational and research system, including the land grant colleges, the State experimental stations, the Extension Service, and the Agricultural Research Service. These are the cornerstones of the development of technology and the assimilation of that technology which has made American agriculture great.

This will not and cannot happen overnight. It may take 20 years, but we must make those midvoyage directional corrections to steer us toward these objectives. At the same time, we must keep our discussions and attitudes positive.

Through innovation, let us keep American agriculture No. 1. American agriculture, the American consumer, the people of the world and the future of the people yet to live on this Earth shall be the benefactors.

[The prepared statement of Mr. Lanphier follows:]

Prepared Statement of Robert C. Lanphier III

NEW DIRECTIONS FOR AGRICULTURE: Science and Technology of the Future

This Joint Economic Committee Hearing "New Directions for Agriculture: Science and Technology of the Future" is the very story of agriculture, this is the recurring theme throughout man's history of survival. This is why agriculture is the most dynamic, the highest technology industry in the world. We the people, as consumers and taxpayers, and you the Congress, as our elected officials to determine policy, are and will be a very necessary and a very important factor in that high technology industry. What research, what innovation, what high technology has not been applied to and has not become an integral part of agriculture?

Congress is to be commended for the time and effort being dedicated by this Committee, by other Congressional Committees and by the Office of Technology Assessment in focusing on the importance of new technologies on agriculture and their interaction with agricultural policy.

When will basic research, new knowledge, innovations, high technology in agriculture . . . no longer be required?

- When we have provided adequate nourishment to the world's population, and
- when we have halted the growth of the world's population, and
- when we are no longer degrading our soil and our environment, we are no longer depleting our water and our other natural resources, and
- when we have no concern for pests, droughts and other adverse conditions, and
- when we no longer wish to improve the quality of available nutrition, and

° when we can accept the true economic cost of both global subsistence nourishment and economically available, satisfying food.

Then will agricultural research no longer be required. None of these six situations exists today. Dr. Norman Borlaug, upon receipt of the 1970 Nobel Peace Prize said, "I believe it is far better for mankind to be struggling with new problems caused by abundance rather than with the old problems of famine." So, we are going to continue to have agricultural research, we are going to continue to assimilate new technologies. But, what are the priorities?

It would be repetitious to reiterate the quantitative importance of agriculture to this country . . . to recite the productivity accomplishments, the productive capabilities, the quality and the diversification improvements which, even we too often take for granted, let alone the American people.

The American people, let us not forget who they are. They are our customers . . . both as consumers of our products and as taxpayers paying for public funded services.

What do these people really want from agriculture, what do the informed people of this country expect from agriculture and, in addition, what would they like from agriculture? We would all agree that the people's wants would be quite different for food commodities than for fibre products such as cotton, and for other non-nutritional commodities such as tobacco.

If you asked every American what he wants from agriculture, what would be his priorities? Since every want normally has an associated cost, and that cost is eventually going to be paid by the people of this country as either consumers or as taxpayers, they not only have a right, they have a need to prioritize their "wants".

For example, we all travel . . . by air. If everyone who flys prioritized what they want from air transportation, the ranking would probably be:

- First, without a doubt - we want Safety . . . today we make a reservation on a small airline, anywhere in this country, with confidence that it is safe. Similarly, we feel confident that the large airlines are maintaining their safety standards despite our reading about their heavy financial losses . . . because we have a government certification process, the Federal Aviation Agency.
- Second, we want Airports . . . airplanes need places to land in order to get us to our destination. Airports are built by communities to afford that privilege, and to encourage economic development through better transportation.
- Third - we want to fly at a Reasonable Cost . . . we're willing to pay more for the speed of getting there, but here there are economic alternatives to flying. Initially, government subsidies were necessary to make flying economically feasible.
- Fourth - we would like a high Frequency of Flights . . . this is not too important, as we have learned how to schedule around just one flight a day to overseas destinations. This want, therefore, should be of far less drain on public funds.

In summary, frequency of flights is less important than reasonable cost, reasonable cost is less important than not being able to fly into a specific location due to no airport; and there not being an airport is less important than crashing enroute. The people have stated their priorities and given direction to their elected officials.

Now to agriculture, what are the people's wants from agriculture?

- First - an adequate, even abundant supply of food, a want we take for granted in this country. In the same speech, Dr. Borlaug said, "Almost certainly . . . the first essential component of social justice is adequate food for all mankind. Food is the moral right of all who are born into this world".
- Second - food at a reasonable cost. In trying to address this "want", some say we have a "cheap food" policy in this country.
- Third - safe, high quality food. This is a subject of growing concern as researchers have analytical measurement instruments of higher accuracy, and as we strive to eliminate the remotest causes of disease, primarily cancer.
- Fourth - food, as the product we produce more efficiently than any other, for export to help balance our trade deficit.

In addition, food stamps, school lunch programs, rural living conditions and other socio-economic wants need to be separately considered and prioritized.

Considering these first four "wants" of agriculture:

- An adequate food supply immediately dictates:
  - a minimum productive capability for each selected commodity, and
  - a reserve program for each of these commodities.

- Reasonable cost dictates:
  - production efficiency to minimize costs, usually referred to as productivity, and
  - since higher risk implies the need for a higher rate of return and thus higher costs, we must minimize the risk to the producer through better methodologies and some form of catastrophic insurance program.
- Safe, high quality food dictates:
  - better quality assurance techniques and safeguards, plus
  - improved food products, both for nutritional value, and for intrinsic safety.
- Exporting commodities requires:
  - a competitive global marketing structure, and
  - additional productive capability from either more input of our resources or from greater productivity.

Through innovation . . . through technology . . . through research . . . we will continue to better address each of these costs, these options, as well as to meet other "wants" of the people.

"Wants", as I said earlier, normally have a cost, there are few exceptions. We can quickly identify three types of costs for these agricultural "wants": There are commodity oriented payments, there is the consumption of natural resources and there are public funded longer term programs. Commodity oriented payments would include the cost of reserves, a catastrophic insurance program and competitive international marketing programs. But, at this Hearing, we are particularly concerned with the last two costs, and how they are directly affected by new emerging technologies and by future farm policy. Before addressing these costs, let us examine one new technology and the changes it has made and is making to farming practices.

Looking back to just 1850, 79% of all power came from farm animals, 15% from humans and the remaining 6% from water. The Power era came and prospered with the tractor. The Productivity era came and prospered with farm mechanization, hybrid seed, chemical fertilization and pest control. During this time there has also been a total change in food distribution modalities.

The future will encompass:

The Information era and

The Biotechnology era.

all in a new worldwide agricultural economy.

These will come because of the introduction and the assimilation of new technologies, technologies that will continue to make American Agriculture the most productive in the world, technologies that will preserve food and fibre products as our country's most important export commodities, technologies that will provide the American consumer with a plentiful and varied supply of food. American agronomists will be the researchers into these technologies . . . the innovators of these technologies . . . the assimilators of these technologies . . . and all of us will be the benefactors of these technologies.

As an example, one with which I have some familiarity, let us examine the Information Era.

The Information Era,encompassing information systems, brings a relatively new technology to agriculture, a technology that is going to have a significant impact on the future of agriculture: an impact that we need to more fully comprehend; an impact that will be felt in the continuing economic battle to bring demand for our agriculture products in line with greater productivity; an impact that will have added importance as the results of biotechnology become commercial reality in our industry; and an impact that, going beyond agricultural mechanization and productivity, will contribute to the socio-economic changes in rural America.

Our challenge is not only to implement this and other new technologies into new applications and commercially successful products, but to do so with an understanding of the economic and of the social impacts such technological changes may foster.

But first, let's define how we use this word - agriculture. Agriculture itself is a broad term, perceived by most to include the production, the storage, the handling, the processing and the distribution of food and fibre products . . . distribution to the ultimate consumer. To put agriculture into a more specific focus, I will be discussing primarily the production of food and fibre until it leaves the point of production, that is up to the "farm gate". But let us not forget when we use the term agriculture, it has far broader ramifications.

Information systems, through electronic technology, can and will provide more sophisticated solutions to the needs of agriculture. But, as engineers and marketers, we must not lose sight of our real objective in incorporating electronic technology, a technology which cannot till the soil, it cannot plant seeds, it cannot protect our crops from drought, hail, pests, fungi or weeds, it cannot harvest our crop and it cannot store our crop. What we are doing is providing the producer with an improved management information system. Electronic technology is one means of developing the instrumentation which can be a part of a simple supervisory information system . . . and must be an integral part of any complete closed loop farm management control system. Thus we are really concerned with providing the sensors, interpreting the signal from each sensor, creating a comparative signal and developing a response capability to this control signal; plus the integration of the transmission and processing functions inherent with incorporating these input and output signals into a customized farm management system.

The needs of the farmer have not changed in several thousand years and probably will not change for a few centuries to come, it is only the level of sophistication of the ways in which these needs are met which constantly changes. There are certain basic functions, such as tilling the soil, adding nutrients to the soil, planting the seed, cultivating, harvesting and storing the crop which were as prevalent in the earliest recorded history of man as they are today.

As we examine these needs, it can be observed that everything grows in an environment. The environment can be soil, it can be water, it can be air, or it can be a living organism existing in one of these environments. Water and air are fluid and reasonably homogeneous, permitting easier modification and control as an environment, such as: the natural nourishment in a clean, moving stream, the addition of nutrients to moving water in aquaculture, the movement and temperature control of the air in a confinement hog barn or the life support from the clean air we breath. Soil, on the other hand, is radically different, often even within a single field, and requires preparation before offering as friendly as possible an environment for a seed to grow and to develop a satisfactory root structure. Since early man's primitive tools, to the moldboard plow, to today's conservation tillage techniques, a seed bed has been prepared in the soil. With more recent methods of tilling the soil we have introduced new problems such as soil compaction and soil erosion. Today's techniques require exceedingly more energy both in fuel and in the production of farming equipment, a consumption of energy that needs to be minimized. Today, electronic instrumentation is improving tractor efficiency, reducing soil compaction, reducing tire and equipment wear, and assuring uniformity of tillage practices.

Though already existing in one of these three environments, animals, when reproducing or producing by-products, are themselves the other environment within which food or fibre growth takes place. Wool, milk, many drugs and in a sense eggs and caviar are a few of the by-products from these living animal environments.

In the interest of brevity, I will primarily relate to the environment of soil and the growing of grains. Similar processes are involved in assuring an optimum environment of air and an optimum environment of water, and in providing proper nutrients to these environments, just as the roots of plants are kept moist and regularly sprayed with a mixture of nutrients as they grow hydroponically in air.

The environment of the soil has been an excellent conveyor of added nutrients to a seedling. Even today, early practices of using raw manure are still prevalent. How short a time has it been, even in this country, since a fishhead was placed in the seed bed along with several kernals of corn? Today we add nitrogen, potassium, and phosphate using granular fertilizers, liquid chemicals, lime slurries and gaseous anhydrous ammonia injection. But now, through instrumentation, we can carefully control and maintain a uniform application rate in each of these cases. We can even go a step further and vary the rate of application of these nutrients depending on the need of each unit area of soil for which we have a constituent fertility analysis. As yet, we do not have an "on the go" soil analyzer or sensor to provide a continuous measurement of the soil. When we do, the application rate will be automatically varied to give uniform field fertility. This will be customized fertilizer application, a very real challenge with significant economic justification.

Seed must be properly and carefully placed in the environment in which it is to grow, and at a distribution pattern consistent with that environment's capability to sustain growth. In some cases this is done with an understanding by the farmer of the environment and of the plant's or animal's needs. In other cases nature either physically culls or adjusts growth consistent with conditions. Our forests, our oceans, or even fields of cotton are excellent examples of nature's way.

As we are able to obtain more data on the nutrient quality of an environment, we can use this information in regulating the optimum distribution of planting. Electronic instrumentation has been commercially available for several years permitting the automatic changing of the planting rate as the farmer perceived change was needed.

When this perception becomes a continuously measured input, the planting rate will be altered accordingly. This will be customized planting distribution. Dairy herd managers and certain elements of the livestock industry are already carefully monitoring the quality of seed and the timing of insemination or embryo transfer. Orchards and vineyards are carefully laid out and planted consistent with the environment and the nutrients available.

Since the earliest recorded tales of food production, man has been concerned with drought as well as with hail, pests, fungi and weeds, not to mention marauding animals and even man himself.

As protection against drought, today we have various forms of overhead spraying, of flood irrigation, and of drip irrigation for areas where natural rainfall is not adequate. Are we using this valuable water properly? Could we obtain the same results with far less depletion of one of our essential natural resources? The answer is, yes. As we develop the sensing technologies along with better distribution systems we will be able to optimize the use of our existing water reserves and also to bring into production land which today cannot be farmed due to a water reserve that, with today's methods, is inadequate. This will be customized water management, unique to the particular land under each farm management system.

As the locusts struck, as pests and fungi degraded or even destroyed a crop, and as weeds have drawn off valuable nutrients or hindered proper harvesting, man has needed another means to protect his crop. Today, modern chemicals are meeting this need, but the rate of application should be dependent on a unit area's intensity of infestation. Chemicals could be applied more precisely, more accurately if more information were available, a condition which could only improve the quality of our environment, whether air, water or soil. Today, electronic instrumentation can assure uniform application of chemicals. Tomorrow, our farm management information system may receive data on the early presence of pests by satellite infrared detection, along with instructions on the type of chemical, the application rate by unit area and the recommended rate and time of application based on long range weather forecasts. Today, we are still missing a few of the sensing devices for total customized pest management. Genetic breeding of pest resistant plants and the availability of friendly predators as a part of an integrated pest management program may have an important impact on the future of customized pest management.

The final truth in food and fibre production comes at the time of harvest. How many millions, billions of farmers over the ages have gone into their fields and observed the quantity and the quality of the fruits of his labor. How often has he thought, "next year I'd better consider planting a different crop", or "next year I'd better apply more nitrogen", or "next year I'd better plant a bit earlier", or "next year I'm going to try a different method of tillage?" These observations, these thought processes are an integral part of the ultimate farm management system.

As we harvest grain crops today, we know the yield and have some idea of the quality based on the moisture content, plus other factors from the elevators, such as protein and oil analysis . . . but we only have this information for an entire field or at best a truck load. To apply this feedback to the same size unit area for which we can fertilize and plant, we will have to know more about our crop as we harvest, such as at the time the grain moves through the clean grain auger of a combine. Ultimately, we would like to know crop conditions some distance ahead of the combine in order to give the combine time to adjust accordingly . . . on the go customized harvesting.

Though customized harvesting is more feasible in orchards, even here presorting for quality remains a goal. In milk production, on-line analysis of milk and cow health at the time of milking will provide continual feedback to the much shorter production interval of the feeding/milking cycle. Fat and weight tests on live hogs are today providing some feedback into swine operations decisions. Individual animal identification has even greater need if we are to properly monitor and control the productivity of each animal and thus of the entire herd.

This leads to the next big step forward in operational farm management. Just as we want to identify animals or plants which are capable of changing positions in air or water, we will require being able to know where we are in a field.

With accurate instrumentation for determining field position, we will then be able to know for any given unit area, for example, the fertility of the soil. A unit area may be a square meter, a square rod or an acre. We will then apply only the necessary nutrients . . . nitrogen, potassium, phosphate . . . to each unit area, and we will plant the optimum seed population based on the new level of fertilization of each unit area. We will know the level of pest or weed infestation in each unit area, and we will apply only the needed amount of chemicals (or friendly predators) in each unit area. We will know the yield and the crop quality for each unit area . . . information which will give us a new data base or add to a continually growing data base for the planning, for the managing of the next year's production.

Except in those areas where food is plentiful year around, man has always been concerned with storing food. Today we may store food products for reasons that are more economic than survival related. But the problems of bacteriological degradation and of depletion due to rodents or even larger animals still exist. Let us not forget that many a conquest during man's span on earth has been triggered by a neighbor's need for food.

Today, the economic, the political and the emotional factors make this issue far more complex. The individual farmer may consider his stored grain an investment on which he wants a profitable return, but other constituencies look at food reserves, existing surpluses, production over-capacity, world hunger, subsidized cost of storage, trade balances, and so on, a bit differently. Regardless of the reasons for storing food, loss is highly undesirable. Today, electronic instrumentation has proven by far the best means of measuring the temperature of grain throughout a storage bin, where increases in temperature can be an early indication of bacteriological activity. We still have much to learn in effectively and economically detecting potential degradation and depletion in crop storage.

And thus, we have completed the farm process, and we are back to tilling the soil in preparation for another crop. If decisions that are made from plowing, to applying chemicals, to planting, to harvest, even through storage, can be termed operational planning, then the decisions that are made prior to preparing the soil, prior to insemination of a dairy cow, prior to the long term investment in replanting an orchard . . . are strategic planning. While developing the sensor or transducer may be the most critical and the most elusive part of our task, it is the total farm management system which is going to be of ultimate benefit to our farmer-customer.

Today, electronic instrumentation, what we at DICKEY-john call Agrionics$_{(R)}$, is an accepted part of production farming. Virtually every new planter is purchased with a seed monitoring system, cotton harvesters have monitoring systems, grain combines are monitored for early detection of problems as well as the amount of grain lost after threshing, sprayers and spreaders have closed loop control systems to assure uniform application of chemicals, tractors and combines have, as a minimum, electronic digital tachs, with more sophisticated information systems coming on the market with the introduction of each new model. Today, many farm equipment dealers, and even some farmers feel comfortable replacing a sensor or a plug-in circuit board or even trouble shooting a system to locate a troublesome intermittent.

As we move into other facets of agriculture, instrumentation has long provided a means for measuring the moisture content in grains and forages, and more recently can do rapid analysis of protein, oil, fibre and starch using near infrared techniques. Instrumentation is used for measuring protein, butterfat, lactose and water in milk. Instrumentation is used for counting the somatic cells in milk for mastitis detection. Instrumentation is used for rapidly measuring the fat or lean content of ground meat. Instrumentation has already solved many agricultural problems where there was a need.

In the very near future, we will see with the aid of electronics:

° The quality of our agricultural output will be monitored and identified from producer to the supermarket or retail outlet. Milk will be graded by butterfat and protein by cow at the farm at the time of milking. Mastitis detection at the time of milking will give dairymen a better chance to take corrective action.

° Non-intrusive methods of fat and protein analysis of live animals will improve feeding programs at an excellent savings once automatically controlled feed formulation systems are in place.

o Fast measurements utilizing energy reflectance and transmissive techniques will replace classical wet chemistry procedures for analyzing the composition of agricultural products such as protein, oil, water, starch, sugar and food fibre in grains, oil seeds, milk, forages and animal feeds.

Today, electronics are being routinely used to solve productivity, efficiency, operator fatigue and operator convenience problems on the farm.

The future diagnostic instrumentation will detect equipment problems at their inception and inform the operator through a visual display, or vocally, as to the seriousness, the corrective action, and/or the repair procedures -- it might even tell him the nearest dealer stocking that part and reserve that part in the dealer's inventory before the operator has time to even stop the machine.

Yes, the Information Era through electronic instrumentation is a new era in agriculture.

When does a "new era" begin? Twenty years ago, instrumentation on the farm was almost limited to mechanical tachs and fuel gauges; the transistor existed almost solely in the tractor radio. Since then, electronic instrumentation has developed from discrete components

to transistors;

to RTL logic, the first step in small scale integration;

to T^2L, another step in small scale integration;

to CMOS, complementary metal-oxide semiconductors;

to the first large scale integration in the form of custom integrated circuits;

to multi-chip microprocessors;

to single chip microprocessors.

This many advances in technology in less than two decades! Displays have gone from incandescent lamps, to Nixie tubes, to light emitting diodes, to liquid crystal displays, to CRT's. A year or so ago we spoke of the future of speech synthesizers, failure prediction algorithms, fibre optic sensing . . . they are here today. Tomorrow will give us even faster and better tools with larger and faster memories, more powerful microprocessors, optical logic circuitry, artificial intelligence, computer vision systems, sensitive tactile sensors, and on and on. Of course, we can add to that list the advent of farm management computers.

With this technology at our fingertips, we must not lose sight of the real needs of the customer who is going to pay for this instrumentation. There is no doubt that we could have designed and produced far more sophisticated instrumentation over the last 20 years . . . and can today . . . but would it have been, will it be commercially successful? This is essential, because only through commercial success can we finance future developments and future new technologies.

This Hearing is concerned with the interaction of this type of new technology and with future farm policy, and how these new technologies and how future farm policy will impact on two of the costs required to meet the people's "wants" of agriculture: the cost of consumption of our natural resources and the cost of long term programs which are publicly funded.

Without technology we were only servants of the land, of the water, of our environment. We had to toil to feed ourselves, to survive. Technology has broken these shackles and has given us a new responsibility, a new challenge: to be stewards of the soil, of the water, of the air. Only through technology can we be stewards and not servants, and only through assimilating new technologies can we be better stewards while meeting the changing needs of a growing world population.

- We can have soil degradation or we can have soil preservation.
- We can have water depletion or we can have water management.
- We can have chemical contamination or we can have safe levels of residue.
- We can have environmental pollution or we can have clean air, streams and lakes.

American innovation, technology and research have given us the competency to address these challenges. Whatever may be its flaws, the greatest educational system in this country, supported by both state and federal funds from the public sector and by additional grants and funding from the private sector, has given us our premier position. There are those who may criticize, but when you're number one, you must have done a few things right.

Just as prior technology has combined with the great American system of capitalism and private enterprise, with the entrepreneural spirit of the farmer and with our great natural resources to make American agriculture the most productive in the world, and, through greater productivity, to make American agriculture this country's premier industry; together they will continue to give America the world's greatest ability for providing the world's most needed commodity . . . and at the same time, sharing, exporting our new innovations, our knowledge to reduce starvation and malnutrition throughout the world.

The private sector's role in making new technologies commercially available is directly and indirectly affected by public policy decisions. Of particular direct importance is the whole issue of property rights, where private funded research by public bodies is concerned and in the area of biotechnology. Agribusiness is taking a much greater interest in public policy after their severe problems of the past few years. Such recessionary problems result in:

1) reduction of investment in corporate research.

2) reduction of funding and grants to research institutions.

3) delay of introduction of new technologies and new products.

4) reduction of participation and funding of technical societies in such areas as where industry standards are established, and

5) a slowing of acquisition of new ideas.

Reasonable analysis of the impact of new technologies need to be made, but such impact studies may be greatly influenced by the forces driving the marketplace to assimilate a new technology. Bureaucratic procedures and paper work will be the handmaiden of those who use impact studies to thwart continued advances in agriculture.

Technology is the answer to the ultimate objective of providing an adequate supply of food both domestically and for international trade through efficient farming while preserving our natural resources and maintaining a viable rural life, recognizing that some will survive, and that some will not. The American system can achieve this ultimate objective.

Research must go beyond today's needs or even those needs we can anticipate for tomorrow. Research must give us a wealth of technologies upon which to draw. When we will adopt these technologies will be determined by the marketplace. The marketplace may be driven by economic forces, or by regulatory or legislative requirements, or merely by customer demand. Technology cannot anticipate the needs of the marketplace, and though the marketplace may put priority on certain types of research, the marketplace cannot wait for technology when the need arises. Research must give us an excess of technologies upon which to draw. To do this we need to concentrate our efforts in three areas.

First, we must work for a positive farm policy. This will only occur when the Administration and the Congress have a clear perspective as to just how the people of the United States feel about the role of agriculture in our nation's future. What do the people of this country want, and what are they willing to pay . . . NOT what do special interest groups want, and how much are they willing to demand. We must address, as separate issues, an agricultural policy relative to the efficient, profitable farms which can meet our domestic and international food requirements, versus a rural policy for the one and a half million small farms which cannot compete. Such an approach could well result in eliminating unworkable commodity programs and, instead, instigate income supplement programs that reflect the need to deal with the socio-economic needs of Americans living on farms in rural America, as contrasted to agricultural programs related to economically sustainable farm production units.

With the same determination, we must clearly identify our public funded research efforts for preserving our soil, water and other natural resources, for protecting our air and water environments and for improving the nutrition of our people. We must adequately monitor public funded research versus private funded research, and higher-risk basic research versus applied research, in areas such as genetic engineering and other sub-disciplines of biotechnology, in integrated pest management and in new mechanization modalities and sensing methodologies which let us continue to increase our productive capability and improve our management expertise.

We must separate and identify these agricultural programs from the research activities directed at rural institutions; a priority that may no longer be as representative of the peoples' wants as it was in 1862.

Second, the Congress, the Administration, our Governors and our Land Grant Colleges must put aside pork barrel goodies, special interests, good 'ole Charlies, and re-inventing the wheel except for instructional purposes. They must utilize cooperative, multi-disciplinary approaches in place of both inter and intra duplication of disciplines. They must determine how we can most effectively utilize the billions of dollars we have available to continue an outstanding agricultural education system and to fund the thousands of highly dedicated researchers. There is a concern that not enough bright young minds are coming into agriculture, an industry that utilizes virtually every high-technology discipline. Secretary Block's 1984 Challenge Forum along with subsequent sessions have addressed these issues, including incentives, internships, classroom education and particularly the high-tech image of agriculture.

Let us not forget what the September 1983 CAST report stated so well: "Additional farm income will not come out of marketing margins, but will come from taxpayers, consumers or improved farmer efficiency. Investments in research and extension to improve farming technology, management and marketing contribute to efficiency gains, and they benefit the whole population more than they benefit farmers".

And third, we need strong direction and prioritization of all of these efforts. The 1981 Farm Bill established the Office of Assistant Secretary of Science and Education, which, for the first time, consolidated under one authority all of the various parts of our educational and research system including the Land Grant Colleges, the State Experimental Stations, the Extension Service and the Agricultural Research Service. These are the cornerstones of the development of the technology and the assimilation of that technology, which has made American agriculture great.

This won't, can't happen overnight. It may take 20 years, but we must make those mid-voyage directional corrections to steer us toward these objectives. At the same time, we must keep our discussions and attitudes positive. Remember, the results to date are pretty darn good.

Through research, innovation and new technologies, let's keep American agriculture number one. You have the responsibility and the authority to make the positive policy decisions in 1985 that will keep this country's greatest industry, this country's highest technology industry, this country's most essential industry number one. American agriculture, the American consumer, the people of the world and the future of the people yet to live on this earth shall be the benefactors.

Senator SYMMS. Thank you very much for an excellent statement.

Our last witness this morning before we get to questions is Mr. Michael Phillips, Project Director, Food and Renewable Resources Program, Office of Technology Assessment.

Before you start, Mr. Phillips, the Chair would just like to recess the committee hearing for about 3 to 5 minutes and then we will resume the hearing and try to wrap it up in another 10 or 15 minutes. We will just stand in recess.

.[A short recess was taken.]

Senator SYMMS. OK, gentlemen. We appreciate you all being here and making this possible so we can get all of your interesting statements as part of our record. I particularly appreciate the ideas presented by Mr. Lanphier of which way farm policy is going. When I hear all these modern ideas, in your testimony, Mr. Fraley, and some of the others who have testified on some of the other new things, it certainly makes me think that whatever the farm policy be in this country, it certainly should be one that is based on the free growth of new ideas. We must not bury and burden the potential growth of farm policy by burdening it with cumbersome commodity programs and so forth which in fact might channelize the resources of agriculture in a certain direction when it should be going the other way.

I hope we can keep it where freedom of choice and the market make these decisions instead of government policy planners who may or may not be correct in what they think will happen.

We will hear from Mr. Phillips, and then we will have some questions for the panel.

STATEMENT OF MICHAEL J. PHILLIPS, PROJECT DIRECTOR, FOOD AND RENEWABLE RESOURCES PROGRAM, OFFICE OF TECHNOLOGY ASSESSMENT

Mr. PHILLIPS. Thank you, Senator Symms. It is certainly a pleasure to be invited to appear before you today to discuss the progress of the assessment which your committee has requested from OTA on emerging agricultural production technologies, public policy, and structural change in American agriculture. I am Michael Phillips, Project Director of the requested OTA assessment.

Two previous witnesses, Mr. Fraley and Mr. Lanphier, have outlined the tremendous innovations which are on the horizon in biotechnology and electronics for agricultural production. Mr. Fraley prepared a most significant paper for OTA on the potentials of biotechnology for agriculture and he has participated in the technology workshops OTA has conducted as a part of this study. Mr. Lanphier serves on the advisory panel for the OTA study and has worked with us on identifying the emerging electronic technologies most likely to impact the agricultural production sector by the year 2000. The technologies which Mr. Fraley and Mr. Lanphier have discussed today and others being analyzed by OTA are not blue-sky technologies. Instead, they are technologies which for the most part are emerging or will emerge in the near future. We can expect adoption of many of them to begin in the next 3 to 10 years, especially by innovative farmers. This is the case for animal agriculture in particular. For example, in the dairy sector, as you heard Mr. Fraley mention, biotechnology already is beginning to be used on farms. The two most prominent technologies are bovine growth hormone and embryo transplants. The productivity gains from these technologies are enormous. Our analysis indicates that the bovine growth hormone, alone, can increase production of a cow by 12 to 15 percent per year, and I might add, with no increased feed for the animal. Preliminary results from ongoing studies indicate that milk production of cows from embryo transplants is significantly greater than from cows of natural reproduction or from conventional reproductive technologies.

It is, however, the combined effects from all of the emerging technologies which is of interest in projecting future productivity gains. Let us again examine the dairy sector. Our preliminary analysis indicates over the next 5 to 10 years the most important class of technologies which will impact the dairy sector are biotechnology and electronic information systems. We estimate if the present economic environment and policy programs remain unchanged, the combined impacts from technological advance will have the potential to increase the national average milk production per cow 14 percent by 1990 and 43 percent by the year 2000. This translates into a 2 percent per year annual increase in milk production from now to year 2000. Such dramatic increases in milk production potential, coupled with a static demand for milk since 1977, indicate a continued surplus situation for the dairy industry. Such a situation will result in significantly larger treasury outlays than the $2.6 billion which was required for the dairy program in 1983.

The adoption of these emerging technologies raises many important structural questions. Who will likely adopt these technologies? Will it be the small dairy farms, moderate-size farms, or the large-scale farms? If indeed the near-term future is one of surplus supply, then clearly some farms will not survive. Which farms will go out of production? In a surplus situation costs of production become extremely important. Which size of farms is most likely to have the least cost per unit of production? Our analysis indicates that it will most likely be the large-size farms which will be able to adopt the technologies, which, in turn, will lower costs of production per unit. For example, our results indicate that for a farm to break even in 1984 using embryo transplant technology, it must have a cow herd of at least 300.

Most large dairy farms are located in the Southwest, mainly Arizona, New Mexico, California; and the Southeast, mainly Florida, where the average herd size is approximately 500 cows and the largest 10 percent of all farms average 1,700 cows. Approximately 1,600 dairy farms are located in these regions. In contrast, the lake States of Minnesota and Wisconsin, and the Northeast, mainly Pennsylvania and New York, average herd size is about 54 cows and the largest 10 percent of all farms average 135 cows. A total of slightly over 60,000 dairy farms are located in these regions. Technology and economics will be major factors in shifting dairy production to the 1,600 dairy farms in the Southwest and Southeast by year 2000. Many of the 60,000 dairy farms in the lake States and

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Northeast will not be able to survive by year 2000 based on income derived solely from dairy operation.

The scenario sketched out for the dairy industry is not unique. It is likely to be repeated in most other agricultural commodities. Today a situation exists for U.S. agriculture in which 85 percent of all farms produce only 15 percent of the food supply and 15 percent of all farms produce 85 percent of the U.S. food supply. The large number of farms, approximately 2 million, which produce only 15 percent of the food supply are mainly small farming operations with sales of less than $100,000 per year. A very large proportion of these farmers make more money from off-farm jobs than from on-farm. For many, the farm is a hobby, a retirement enterprise, or a place to raise a family.

The commercial farm sector which produces 85 percent of the U.S. food supply is comprised of approximately 300,000 farms with sales of $100,000 or greater per year. These farmers depend primarily on agriculture as a major source of income. However, it is highly diverse. The commercial farm sector is composed of about 275,000 moderate-size farms with sales between $100,000 and $500,000 per year, and 25,000 super-size farms with sales over $500,000 per year. Super-size farms, which represent only 1 percent of all farms, produce about a third of the total value of U.S. farm products, and account for an astonishing 60 percent of U.S. net farm income. Many of the super-size farms are highly integrated components of larger corporate conglomerates such as Cargill, Conagra, or Ralston Purina. In contrast, moderate-size farms represent 12 percent of all farms, produce 40 percent of the total value of U.S. farm products, account for about 35 percent of net farm income, and relatively few are integrated with agricultural processing-marketing organizations.

I might add that these trends which we have just discussed have been developing for at least 30 years. However, we have reached a point where the numbers are becoming critical and the dichotomy between moderate-size and super-size farm more distinct. The moderate-size farming operations which once comprised the bulk of the agricultural sector, are fast disappearing. Much of today's farm policy is said to be directed toward the survival of moderate-size farms. However, the present direction is clear: If the trend continues the result will be a dual agriculture—few super-size farms and many small-size, part-time farms. This means there will be little, if any, moderate-size farms in existence. These farms will either expand to become one of the large operations or they will sell part of their assets and join the small-size, part-time farms, or exit entirely from agriculture. An important question for policymakers is, what do you want the farm sector to be? Absent changes in Government policies, technological and economic forces will move agriculture to very large, cost-effective enterprises and they will be integrated into the marketing system.

Obviously benefits and costs exist with any scenario of the future. Some benefits from the above scenario are greater efficiency in production of agricultural commodities, possibly lower consumer food prices, and improved competitiveness in the export market. However, some costs come in the form of large numbers of farmers being forced out of agriculture, the potential for quality of life in rural communities to decline, the impact of the extensive use of technologies by large-scale operations on the quantity and quality of water, rate of soil erosion, an increase in air and noise pollution, and realignment of financial institutions to service a large-scale agriculture. As OTA's study draws to a completion next spring, we will attempt to give you some idea as to the relative magnitudes of benefits versus costs under alternative scenarios for the future.

A number of questions exist for policymakers to answer in deciding what they want the agriculture sector to be for the rest of this century. Decisions policymakers make in the 1985 farm bill will help shape the future direction of U.S. agriculture. For example, the decision on the type of farm commodity programs, the attending loan levels, target prices, and effectiveness of the $50,000 cap per farm operator will have a direct bearing in determining who the beneficiaries of the commodity programs will be and, thus, shape the future course for agriculture. Decisions in the 1985 farm bill on the role of public research and extension in agriculture, the emphasis on basic versus applied research, development of extension staff capable of transmitting the complex emerging technologies to farmers, and a determination of who is the clientele of research and extension directly determine those programs' beneficiaries and, in turn, the future direction of agriculture. Even though many view a farm bill debate as only short-run adjustments or concern with level of farm income in the next few years, in reality these decisions have much longer-run implications on the future of U.S. agriculture.

OTA will prepare a special report which will provide information on the issues which will be debated in the 1985 farm bill and transmit it to this committee at the beginning of the 99th Congress. The objective of that report will be to provide committee members with information on the longer-run implications of policy alternatives to be considered in the farm bill deliberations.

Again, I thank you for inviting me to testify today, Senator Symms, and I would be happy to try to answer any questions you might have.

Senator SYMMS. Thank you very much. I think you all have made an excellent contribution here to the meeting this morning.

It was, of course, by design that we had Mr. Phillips' statement, because he rather tied everything together—the promise of agricultural technology and research with the realities of the farm structure and a possible policy.

Now I have a couple questions I would like to direct to the entire panel and I might say at the outset that I think I have run into the same problem as Senator Abdnor had this morning. I have two meetings, both of which are absolute top priority that I am supposed to be at at 11:30 besides this one, so I am going to ask a couple of questions then turn the meeting over to Mr. Bob Tosterud, our senior economist for the Joint Economic Committee, and let him go ahead and continue to lay some of these things on the record, if it's OK with you gentlemen, so that we will have our hearing record completed. My apologies for the lack of attendance for a few minutes, but we do think it is important that we get this hearing record in a form that we can use it next year for the formulation of a farm policy which will be written in the Congress early next year and probably pass some time along the middle of the summer in 1985 in the new farm bill which will be passed in 1985. I think your opinions and what you have to say this morning are very important.

The questions are these: Has agricultural technology and public farm policy contributed, in you opinion, to the concentration in farming? The other question which goes with it is: Is there a need for an average-size farm policy and research that will promote average-size farm operations?

I do not know how you want to start out, whether Mr. Black wants to start off with that or you do, Mr. Phillips, and I would just like to have each one of you have an opinion on that.

I will repeat the question. Has agricultural technology and public farm policy contributed, in your opinion, to the concentration in farming? Then, coupled with that, is there need for an average-size farm policy and research that would promote average-size farming operations?

Mr. PHILLIPS. We will have in the special report that I mentioned, some fairly definitive statements particularly about your first question.

I think from the analysis we have conducted so far, it will be fairly clear that indeed the combination of emerging technologies coupled with public policy for agriculture, i.e. the type of farm programs that we have, the type of credit programs that are available to farmers, the type of research and extension system that we have—along with the economic environment in which we operate in this country, that indeed they have contributed to the situation we find ourselves in today in terms of concentrating numbers of farms in this country.

Basically, for those that have had some economics training, it goes back to a famous economists's theory that has been borne out in what is called the treadmill effect by Mr. Cochran at the University of Minnesota. It is clearly one in which you are on a vicious cycle in terms of being able to cut costs by adopting technologies. Particularly if you're one of the early adopters of those technologies, you have the advantage over others in terms of being able to use that technology first, get your costs down, and at the same time increase your profit.

Those that adopt technologies at a much later point in time do it basically for survival. For if they do not adopt the technology, they are basically out of the industry.

We have seen that technologies coupled with commodity programs in particular have allowed farms to grow in size and provided the incentive to grow to the point where we are facing the situation that we are today.

Now, to address the second question, whether that is good or bad brings in your values, and our report will not be indicating that Congress must have an average-size or moderate-size farm policy. We will essentially be pointing out to you what the direction is. You are going to find those that argue that every other economic sector in the United States is moving this way and what's the matter with agriculture going this route—to the point where maybe all we need are 100,000 farms producing our food for domestic and export use. That depends basically on your values. It depends on what are some of the noneconomic attributes that smaller- and moderate-size farms have to offer.

There is interesting research that we will be reporting on in our report to you next year about some of the noneconomic factors. For example, what happens in terms of relationships between size of farms and rural communities? In certain parts of the country we see there is an inverse relationship. In other words, the larger the size of the farm, the socioeconomic indicators within a rural community decline.

Essentially what you are talking about is a disappearing middle class. It is the middle class that allows these services within a rural community to exist in terms of education and services, etc. There are a number of factors to be considered. There are going to be tradeoffs involved, and I think that will make for some lively debate within the Congress.

Senator SYMMS. Mr. Black.

Mr. BLACK. I'm not an economist, but what Mr. Phillips has said says very clearly what little I've learned about this subject by listening to people like him who know what they're talking about. I would defer to Mr. Blase because he's an agricultural economist and he knows about such matters.

Senator SYMMS. Mr. Blase.

Mr. BLASE. I would agree with Mr. Phillips with regard to the first question.

With regard to the second question, I also agree it is a value issue, but there is one additional dimension that I think needs to be of concern.

There is some evidence that suggests that we are moving in the direction of a British tenure system. The thing that concerns me about the British system is that it has not been a world leader with regard to adoption of new technology.

As we move in the direction of larger blocks of land being held by smaller groups of people and as we move to more of a tenant oriented agriculture we begin to generate problems that seem to me to have some implications for technology development.

Senator SYMMS. Does anybody else want to comment?

Mr. LANPHIER. Mr. Chairman, without taking exception to what Mr. Phillips said, basically most of it, I think instead of the concentration we need to be looking at the economic effect on the cost-effectiveness of farms. I think technology has certainly improved the cost effectiveness of larger farms. There is no doubt that public policy has maintained the farms that are not cost effective and has given them the ability to go on.

This, of course, leads to your second question. Do we need a policy that maintains an average-size farm? I agree with Mr. Blase that this is a value question, but it's two separate issues. That's what, as I said in my remarks, I hope the Congress will do, is address an agriculture policy that addresses the very needs of the people toward agriculture and then separately address the rural socioeconomic problems that Mr. Phillips has outlined, and do not comingle and don't confuse them and don't fuse them together. Keep them separate.

Senator SYMMS. Do you think the supply control farm programs that we have tried on and off very unsuccessfully, in my judgment, because it is like clapping with one hand. I think we have said that before here in this committee, where we reduce production in the United States and increase it somewhere else to take up the slack in the market, whether it be soybeans, wheat, corn, or what have you.

Do you think these supply control programs have hindered the development of new crops in keeping the gains in yields and efficiencies of production of either the same crops or new crops?

Mr. LANPHIER. I don't know that I have enough background to relate directly to that. Certainly the supply management—first, let me say the supply management theories that we have had to date speak for themselves in their ineffectiveness and their costs. We have got to change from these type policies.

There are times when they have certainly added to and brought technology forth rapidly, such as in the 1970's, but those same policies in effect have caused great reorientation in the assimilation of technologies more recently.

I believe people on the other end of the table could probably more effectively speak to how crops were affected.

Senator SYMMS. Gentlemen, I am going to have to ask your forgiveness. I have to go back to Senator Humphrey's office on a matter of computed interest on real estate transactions. I am going to excuse myself and turn the meeting over to Mr. Tosterud to continue on if he has a few more questions, for about 5 minutes, Mr. Tosterud, if you've got some questions.

Mr. TOSTERUD. Will you be back?

Senator SYMMS. I will not be back. I beg your forgiveness and I thank you very much for your contributions to this committee, and I thank Senator Abdnor for pushing forward on this. I do not know what we are going to do with all this information but at least we are going to try to see that next year our farm policy comes out of a Government that at least is on the side of better production and better marketing overseas is what I would hope to see, and that's a tall order. Thank you.

Mr. TOSTERUD. Mr. Lanphier, would you like to continue?

Mr. LANPHIER. No, I had finished.

Mr. TOSTERUD. For the record, I am Bob Tosterud, senior economist of the Joint Economic Committee.

Does anybody else wish to react to the general question of have supply control programs been a detriment of U.S. agriculture?

Mr. BLASE. Just one additional comment. In the 1950's, there were provisions that made it possible for farmers to grow specified "new crops" on set-aside acreage. This is not in the present legislation. It would represent one alternative way for farmers, at relatively low cost, to try experimental growing of new crops. This would be a relatively low cost to anybody concerned given the fact the alternative is that it would be in some kind of conserving use. In most instances provisions could be specified that with the new crop you would still have to retain any conserving use.

So there is a possibility that we could get some additional assistance via programs such as we have now by having a little more flexibility with regard to growing new crops on diverted acres.

Mr. TOSTERUD. I might add that I have a great deal of empathy for the agricultural scientists here today. I have done some work in the area of cost-benefit analysis of new crops.

Would you agree with me that perhaps it is not a very popular notion these days to advocate growing four ranges of grass where only two grew before? I mean, how do we reconcile the supply problems we have in agriculture with obviously your suggestions that we increase the resources devoted to increasing that supply? Mr. Knowles, do you have a comment on that?

Mr. KNOWLES. Well, I would say that if you look at the major crops of the United States, there are massive amounts of research money being spent on them. Almost every State has a wheat breeding program and certainly a great many States have a corn breeding program. So, yes, certainly this research has contributed to the very high yields.

For instance, in California the improvements in wheat and the higher yields of new varieties of wheat have caused wheat to displace some other crops. In barley, for example, the acreage has declined. Safflower in many situations has had a very difficult time simply because of the superior wheat material that's available.

Well, this leads me back to some of the things that were said at the beginning of this discussion, that these newer crops simply need more research to make them more productive. I am pleased that there has been more research on guayule and I think that crop eventually may become established in this country and will provide us with our rubber needs and perhaps displace some of the crops that are problem crops. I don't know whether I've given you a very good answer to this or not.

Mr. TOSTERUD. Well, you did indeed.

Mr. Sampson, do you have a comment?

Mr. SAMPSON. Well, as a layman with regard to the economic aspects of agricultural policy, I have to stand back and look at the sheer concentration of our resources and production in very few crops—and then the base of support they command for additional work on those crops to improve them, and particularly to improve their yields, which compounds our problem. The potential that new crops present for diversification of the agricultural base I think would inherently improve the situation. What we're talking about is not necessarily limited to new food crops. Many of the new ventures in new crops involve industrial raw materials that will not merely offset food that we're already producing out of another crop. They will be net new contributions of U.S. agriculture.

So regarding the point that Mr. Blase made of how we might begin—by encouraging or permiting the utilization of set-aside acreage to begin to gain experience and confidence with new crops—I personally would strongly support that.

Mr. TOSTERUD. From the view of the average taxpayer, you would look at USDA's budget. On one column he sees $30 billion went last year to control output, and then in another area he sees a substantial amount of money spent in promoting output. We are spending some funds in the dairy now, as was talked about by a few of you, and as I understand it, there's also some effort being made at dwart wheats, high yielding wheats.

Are we suggesting that there should be a reprioritization or rechanneling of research funds perhaps to production techniques, Mr. Lanphier? You can understand the confusion of the average populace.

Mr. LANPHIER. Let me just pose a question in response to that. Wouldn't it be better to spend $20 billion paying people to eat our food than paying $20 billion for our farmers not to produce? That's where we really came to a year ago and, yes, we are spending a great deal of money on the demand side and marketing and we ought to continue it. I think as we look at the question the Senator brought up before about the supply aspects of it, we need to know why the supply procedures failed.

I would just like to make one other point in the concentration area. Part of the recent feed grain program was, I believe, that any acres that were taken out of production, in order to qualify, must be put into the conservation work. This has to be a part of any type of subsidy program.

Mr. TOSTERUD. It may not be a supply problem but rather a demand problem is what I hear some of you saying. Certainly there are hungry in this world and we know that, and second, perhaps there is some need for getting new products out of existing crops. Perhaps some funds should be devoted to that area as well, such as gasahol and others.

Mr. PHILLIPS. If this hearing were held 10 years ago, that question probably never would have been asked. It just goes to show that as quickly as we can be in a scarcity situation, we can also be in a surplus situation. And my concern is that policymakers not take the shortsighted view that just because we are in a surplus situation now means we're going to be in one 10 years from now.

Research that we fund today needs a lead time of anywhere from 15 to 20 years before it reaches any kind of fruition. So these are very important areas we have covered here from both the panels in hoping that policymakers do consider a wider diversity of germ plasm and new crops that we need to be conducting research on, as well as to keep working ahead on conventional technologies and cropping systems, because as soon as we can be in a surplus situation we can find ourselves again in a scarcity situation.

Mr. TOSTERUD. You're precisely right. Just a couple of other questions.

I am wondering what role the United States plays in crop development or animal development relative to the entire world. There is talk, for example, and considerable truth to the fact that the United States serves as a defender of the free world and produce the defense materials and all the rest. I am wondering what other countries are doing in this regard in terms of crop development and animal development, productivity gains in food production generally, or are we in fact 80 percent of the world's effort in this area? What is Canada doing, for example? Does it have a comparable program to ours, or the European Economic Community or Australia or Argentina, or are they in fact just adopting ours as fast as we can put them out?

Mr. KNOWLES. Well, this is an economic question and I think Mr. Blase could better answer it. However, I would say that some of the developing Third World countries, are terribly concerned about their agricultural production and do look toward this country as an example or for advice in improving their situation. In those countries, obviously the crops of major concern are the wheat and corn and rice, the energy crops that drive civilizations the world over.

They are now increasingly concerned about oilseed crops as a means to supply their needs for vegetable oil which many of them have been buying in part from the United States. They do need agricultural programs and improvement in their agriculture, not necessarily by adopting our system, but by improving the way they do things so that their yield per acre goes up. Most of those countries have plenty of laborers. The thing that they need is higher yields per acre.

Mr. TOSTERUD. Mr. Blase.

Mr. BLASE. There is no question that the United States has been the world leader as far as agricultural technology is concerned. However, there have been noteworthy contributions that have been made in other countries. Mr. Knowles mentioned some of the work by the Canadian scientists with regard to changing rapeseed oil into edible oil. If I recall correctly, one of the breakthroughs with regard to sunflower production was made by a Russian scientist. There have been others in various parts of the world who have made a contribution.

The largest single research thrust one finds outside the United States is basically located in the International Research Centers, the IRRI's and the SYMIT's and the rest of the system of international centers. And as one works around the world, one becomes increasingly impressed by the fact that there are ties between national agricultural research programs and the international centers, where there is an effort made to adapt the research that is coming out of the international centers.

Mr. TOSTERUD. You mentioned in your testimony several alternatives to promote new crop development, but they seemed to have a national or domestic constraint to them. Certainly you will add a global perspective to those efforts, wouldn't you?

Mr. BLASE. Yes; this is partially because of the fact that almost by definition in the new crops area you have to be internationally oriented. In fact, the bulk of the new crops that we are likely to do research on have to be imported from abroad. As a consequence, there is no question that we have to have relationships around the world in order to identify the germ plasm, import it and begin research on it.

The problem that I think is foremost in our mind is that the resources have been so sparse, even within the United States, that the thought of going worldwide would suggest an increase in resource requirements that might be mindboggling.

Mr. FRALEY. In the area of the development of some of the newer biotechnological methods, several foreign countries have been on the leading edge of research. Japan, for example, has been quite successful in developing modern fermentation technologies. The monoclonal antibody research was initially performed in England. Much of the work on developing systems for introduction of genes into plants has been pioneered in Germany. There is a strong move by the governments of these countries to begin to capitalize on this technology. The Agricultural Research Council in England is starting a large agricultural program. Similarly, the Japanese Government is sponsoring both industrial and university research in these areas.

These countries view the new technologies as a way to bridge the current gap in their agricultural programs. They realize that the basic agricultural research programs in their countries are not very strong relative to the United States—we have a very good base—and the newer methodologies are viewed as a mechanism for narrowing that gap and implementing these methods into various agricultural activities.

Mr. TOSTERUD. From your perspective, Mr. Fraley, in the span of your career, have these activities been rather static? Have they grown or diminished the international cooperation in new foods development and new crops development?

Mr. FRALEY. From my perspective on the development of the newer technologies: I think again as I mentioned earlier, they are being capitalized on and being emphasized now because of their potential to have a substantial impact on agricultural productivity. There seems to be at both the business and the research level, a very reasonable spirit of international cooperation. This is clearly evident from the willingness of some of the European countries and the Japanese to invest in the biotechnology in the United States and vice versa.

Mr. TOSTERUD. Mr. Phillips, do you have a comment?

Mr. PHILLIPS. Yes; I would basically have three observations to your question.

First, along with what Mr. Fraley said, we do have an OTA study on commercialization of biotechnology which substantiates what Mr. Fraley has indicated in terms that the United States when you look at the public and private sector together is probably the leading nation in terms of biotechnology. Japan and West Germany are close on our heels, but in terms of the kind of research patent numbers, etc., this is a shining area for the United States.

However, if you look just at the public sector—and in another study which we conducted on the U.S. food and agricultural research system, we were able to gather some figures of what other countries fund in terms of agricultural research, as well as number of scientists.

If you compare the statistics from the 1950's up through the 1970's, you find that the United States has fallen woefully behind in a relative sense. We had a good thrust back in the 1940's and 1950's and even some of the 1960's. The 1960's are considered to be to researchers one of the golden decades for research funds, but we have tailed off and we have tailed off significantly, and many other countries in terms of their public sector research have really gained on the United States.

One final comment is one of the reasons we have a difficult time answering the question that you posed is that you also find in the research system that we don't have any systematic way of being able to know what is going on in other countries and being able to feed that back to the United States.

Another way of looking at that is, we don't have a way in which to identify technologies that are being used in other countries and looking at its usefulness for the United States. That's basically done on a scientist-to-scientist basis or maybe through one professional society to another in an international setting, but in terms of a systematic way of working through the international centers that we talked about or any other system, through AID and through USDA, there's no place where you can go and ask a question like what you've asked us to address and get any kind of intelligent answer to it.

Mr. TOSTERUD. Thank you. There is a distinct impression that largely because of our supply control mind-set, the bottling up of the genie of agricultural research and technology, the United States is pretty much merchant-in-place, while it would seem like the rest of the world is coming up behind in fast strength. And at what point in time do we yield leadership even in the agricultural science area? It is a fascinating question and one that is uncomfortable to ask at this point in time.

Do you have any comment, Mr. Blase?

Mr. BLASE. Yes; when we look at our commodity programs there are some basic criteria questions that come to mind. Are we primarily evaluating them in terms of the cost of food for the consumers? Are we evaluating them in terms of what has happened to the environment? Are we evaluating them in terms of international exports? These criteria begin to suggest some other kinds of concerns.

For example, there is now evidence emerging that suggests that it is in fact possible that we are seeing higher rates of erosion in recent years which may be—indirectly, if not directly, related to some commodity program. So it occurs to me that there is a challenging requirement for someone to consider how we can strengthen and build in some concerns about our environment into the 1985 farm legislation.

Second, with regard to our role in the world, one of the concerns we have to have is where will the growth in demand come from abroad? Here, the evidence is fairly clear that the growth is most likely to come in the developing countries and that it essentially translates into our having a selfish interest in expediting the economic development of especially the low-income countries. That is where the income elasticity of demand is very high for agricultural commodities and, as a result, there is a possibility that we would see significant increases in exports.

I heard within the last year Peter McPherson, the Administrator of AID, indicate in an oral presentation that our total U.S. exports to South Korea in the last year amounted to more than the total of all the foreign economic assistance we gave that country in the post-Korean war period.

There is no question that if we can get economic development moving in Third World countries, that is where the big stimulus will come, especially in agriculture. That is what market development is all about. It is not about the idea of who are we going to sell soybeans to tomorrow. Market development really means the long-range process of trying to get economic development going in those countries so we can have more buyers.

Mr. TOSTERUD. And as to that, agriculture is the only business I know of where 80 million new customers show up every year, the net increase in the world population basically.

I have just one more question and it is rather topical. On the front page of the Washington Post yesterday there was a catchy headline article about genetic and biological engineering, experiments involving farm animals. "The scientists are trying to create super animals for the future." The article implied that human genes are being used in some experiments.

Would you gentlemen please comment on the economic, biological, and even the moral considerations of genetic engineering of this type?

Mr. Fraley, you have been nominated to respond initially to that question.

Mr. FRALEY. I did not know whether I needed to talk about the animal growth hormones this morning because I thought everyone was so well-versed on them.

I think technically it represents an area of a tremendous amount of misunderstanding. Animal growth hormones: Bovine, porcine, human growth hormones are protein molecules that have been very well characterized with respect to their structure and amino acid sequence. These molecules differ from each other by only a few amino acids. They are very similar molecules.

The experimenters were using the human growth hormone gene simply because of its availability; because of its close similarity to the animal growth genes it would make no difference in their experiments.

For commercial applications that would be likely to evolve from genetic engineering experiments using growth hormone genes, scientists would undoubtedly use homologous genes; that is, bovine genes in cattle, porcine genes in pigs.

There has been a general misconception regarding actually how the animal growth hormones work. In one of the more publicized studies, rat genes were introduced into mice and the resulting mice were increased in size by 10 or 20 percent. That really had nothing to do with the fact that it was a rat gene in a mouse. It simply had to do with the fact that the levels of the growth hormone in the mice were elevated. Inserting additional copies of a mouse growth hormone gene would have worked equally well.

Likewise, putting an elephant gene into a cow is not necessarily going to increase the cows size. Simply increasing the level of the cows own growth hormone is very sufficient for that.

Mr. TOSTERUD. Thank you very much.

Are there any other comments on that? I take it we cannot expect in the near future a cow with a tremendous desire to purchase a condominium. [Laughter.]

Do any of you have any final statements or comments you may want to make at this point before the hearing is closed?

Mr. FRALEY. I would just like to reiterate on a comment that Mr. Phillips made earlier. It's clear to certainly everyone on the panel and in this room that technical innovations have contributed to our capacity to increase productivity in American agriculture. These innovations have certainly been a major contributor to our high standard of living, both in this country and around the world.

Right now we are currently in a period where we enjoy a relatively high level of economic prosperity and we are very fortunate to have surpluses in our agricultural products. Mr. Lanphier pointed out that technology cannot anticipate the marketplace, whether it's the result of developing foreign markets or increasing domestic demands. Likewise, we cannot anticipate possible future scenarios which might very well tax our agronomic production, whether that be drought or increased erosion or other catastrophic events.

I think it's very important for us to consider that if moderate farm policy means moderation in the rate at which technology can be developed or incorporated into our society, such policy could seriously jeopardize our ability to respond to unforseeable demands and to maintain our current high standard of living.

Mr. TOSTERUD. That is a good point. Thank you. Any other final comments that the panel might have?

Mr. BLASE. One further amplification. On the six alternatives in our report, we have indicated that regardless of the other five alternatives that the sixth one deserves attention in and of itself. I mentioned as an illustration just one specific illustrative alternative under No. 6; that is the possible freeing up of diverted acres for growing new crops.

I would like to also indicate that if we are serious as a society about diversifying, about trying to provide more variety in our diets, if we are concerned about providing a means of reducing costs, that it may well be that some forms—either tax incentives or some type of interest subsidies—would be appropriate in the new crops area. It is a high-risk area. There is no question about that. The probabilities of success for any one crop are relatively low. Yet when you look at the totality of the possibilities and recognize that the benefits are likely to be to the American consumers in general, then it becomes a problem for individual firms making high-risk investments when over the long pull the American consumer is the one who is going to benefit.

So as an agricultural economist and speaking only for myself at this point, it occurs to me that in fact there is some economic logic that says that we can afford to spend some public funds in order to try to develop this area of economic growth in our society.

Mr. TOSTERUD. How does one put a value on adequate supplies of food at reasonable prices?

Mr. LANPHIER. Would you repeat that?

Mr. TOSTERUD. How does one put a value on adequate supplies of food at reasonable prices?

Mr. LANPHIER. I think the consumer does that. He is a taxpayer and he is a voter.

Mr. TOSTERUD. Do you have any final comments, Mr. Lanphier?

Mr. LANPHIER. No.

Mr. TOSTERUD. Thank you very much for coming. Mr. Phillips.

Mr. PHILLIPS. No.

Mr. TOSTERUD. Mr. Sampson, do you have any final comments?

Mr. SAMPSON. Just one. I'd like to refer back to something you mentioned; that is, the possibility of developing alternate uses for existing crops. I'd just like to inject a note of caution into that. Obviously, the development of alternate uses that can consume crop surpluses is a very attractive concept; however, we must, in those types of programs, maintain focus on their economic value. That is, any new use requires that a considerable investment must be made in order to develop that use and the means to support it. It needs to be based on a continuing supply of materials, not just utilization of surpluses. It's very easy to develop new uses that become new subsidy programs. There are some examples of alternative uses that have been successfully developed. The high fructose corn syrups, for example, are successful today because they are economically attractive under ongoing circumstances. However, gasohol and fuel alternatives are conceptually very attractive, but in practice they can quickly become new subsidy programs and not stand on their own economic merits.

In net, I think the area of alternative uses merits attention and study; however, the opportunities are perhaps more restricted, and the gains to be made are not necessarily quicker or simpler or surer than in the new crops area.

Mr. TOSTERUD. I appreciate that. Mr. Knowles.

Mr. KNOWLES. No comment.

Mr. TOSTERUD. Mr. Black.

Mr. BLACK. I have one little simple thing I'd like to bring out at this point. I brought along a picture that I'd like to give you and have you pass that along to whomever it might be useful to because I think it will give some perspective about the new crops business that is easy to understand. And as Confucious said, "One picture is worth 10,000 words."

We tend to think of our current crops as having been in this form ad infinitum, but this picture shows cobs of corn unearthed from dry caves in Mexico dated from 5000 B.C. on the left to 1500 A.D. on the right. The one of the left, the corn at that time, 5000 B.C., produced a cob a little over an inch long. And on the right, 5000 A.D., the Indians had developed corn to the extent that the cobs were 5 inches long and it was getting to be a pretty fair crop at that time.

Now it was some years after that when our modern biotechnology in the form of plant breeding began, and now we produce quite a bit better corn than that.

But the point is, these people recognized that the crop in the first place wasn't too much of a crop and they kept selecting it and selecting it more or less unknowingly, and it got better.

The moral of this, in my simple-minded view, is that I think that when we look at something now that somebody thinks might be a potential crop, we see it as it is. We can't see the genetic possibilities that exist to make it better, and people that do that kind of work often get some condescending sneers from their colleagues because of fooling around with some kind of weed, or the seeds fall on the ground, or something like that. The Indians had those problems too, but they kept working at it over 6,000 years, and their corn got quite a bit better.

Mr. TOSTERUD. Thank you, Charlie. Your point is exceptionally well made.

I only have one final comment. The Joint Economic Committee has held somewhere in excess of 30 hearings in the agricultural area. Almost all of those have been looking at the U.S. agriculture as a problem. People talk in terms of agriculture as a problem to be minimized. This hearing today strongly suggests that agriculture ought to be viewed as an opportunity to maximize and be thankful for it.

My sincere thanks to all of you today for coming and I express the appreciation of Chairman Jepsen and Senator Abdnor and Senator Symms. All three are very excited about this hearing and this topic. Thank you again.

With the permission of the Chair, the committee is adjourned.

[Whereupon, at 12:15 p.m., the committee adjourned, subject to the call of the Chair.]

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