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9. ABSTRACT
In this review of building agricultural systems in developing countries, the following topics are examined in detail: 1) the U.S.'s agricultural research base, 2) agricultural research organizations in the developing nations, 3) technology in U.S. technical assistance programs, 4) adaptive research, 5) specialized agricultural research institutes, and 6) strengthening national research systems. From this study it was concluded that world food deficits reached a critical stage in 1965-66 as the culmination of a continuing neglect of agriculture and of agricultural technology in the developing nations. However, special intensive food grain production programs in Asia's developing countries from 1966 through 1968 have brought many of these countries to approximate food grain self-sufficiency or to the expectation that their domestic requirements could be met within a few more years. Nevertheless, short-term food grain production campaigns have not ended the food-population crisis but merely have bought more time. Food needs are being met in part by improved wheat and rice varieties but will depend most heavily on improved technology. The development and adaptation of this new technology to meet future needs must be made increasingly in and by the developing nations themselves. Deficiencies in existing national research capabilities in the developing countries have numerous factors, many of which may seem minute but for which there is no single solution. They can be determined only by a thorough study of each national situation. Substantial progress could be made by strengthening national research systems through moderate modification of the several individual projects supported by a variety of national, international, and private organizations to ensure positive contributions to the institutional building objectives.

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Building Agricultural Research Systems In The Developing Nations

Albert H. Moseman

Associate, Agricultural Development Council, Inc.

The Agricultural Development Council, Inc.
630 Fifth Avenue, New York, N. Y. 10020

About the Author . . .

Albert H. Moseman, an Associate of the Agricultural Development Council, has been concerned with agricultural research since the early 1930s when he arranged for the initial test-demonstrations of new corn hybrids in northeast Nebraska on his family farm. His employment by the Bureau of Plant Industry of the U.S. Department of Agriculture from 1936 to 1940 as a college student assistant in the hard red winter wheat improvement program cooperative with the agricultural experiment stations of Nebraska and other states in the Great Plains area provided a working insight into this coordinated regional research effort and the national program of which it is a part. This experience was applied in participation in the seed flax improvement research project conducted cooperatively by the USDA and the Minnesota Agricultural Experiment Station, in developing this activity into a coordinated national effort during the World War II years, with cooperative research and testing at 45 locations in the United States and Canada.

In 1944 Dr. Moseman was appointed Assistant to the Chief of the Bureau of Plant Industry, Soils and Agricultural Engineering at the USDA Plant Industry Station, Beltsville, Maryland, with principal responsibility for program planning and coordination of the newly merged crops, soils and agricultural engineering research units. Research administration continued to be a full-time responsibility from 1951 through 1953 as Chief of the Bureau of Plant Industry, Soils and Agricultural Engineering and from 1953 through 1956 as Director of Crops Research of the USDA.

As a member of the first team sent by the U.S. Department of State, in 1950, to discuss with foreign governments the possibilities for collaboration under the pending Point IV program, Dr. Moseman had an opportunity to assess national agricultural research capabilities in developing nations of the Near and Middle East, South Asia and the Far East. His return to India in 1955 as a member of the Joint Indo-American Team on Agricultural Research and Education led to the invitation to join the staff of the Rockefeller Foundation to assist in implementing the team recommendations. Major attention was given to the strengthening of India's national agricultural research system.

During his years as Director of the Foundation's Agricultural Sciences Program from 1960 to 1965 the cooperative wheat and maize improvement research activities of the Foundation were expanded into broader international dimensions. The widely adapted Mexican wheats and the International Rice Research Institute emerged in this period. Dr. Moseman gave particular attention to the strengthening of national research systems in the countries in which the Foundation had cooperating programs. Planning of the new facilities for the National Institute of Agricultural Research at Chapingo, as well as for the outlying research stations in Mexico; the development of the Colombian Institute of Agriculture as a national research system; and the continued strengthening of the experiment station organization in Chile received special emphasis.

Dr. Moseman's continuing close association with the U.S. foreign aid programs, including two years as Assistant Administrator for Technical Cooperation and Research in USAID, together with the previous experience with a major private foundation and with the coordinated program of the USDA-state agricultural experiment stations, have provided a unique opportunity to assess the status of and potentials for science and technology in developing nations. This experience has brought about a deep conviction that the international base of agricultural research must be broadened and strengthened by building national capabilities if agriculture is to move and keep moving in the many food deficient nations of the world.

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Chapter I

INTRODUCTION

The severe drought in India in 1965 focused attention on increasingly critical worldwide food shortages. Professional agriculturists and demographers for many years had shared a deep and growing concern over the steady decline in per capita food supplies in the developing nations. But it took the stark reality of potential widespread famines in many of the developing nations to bring this problem to the forefront in the thinking of political and administrative leaders of the developing nations and in the organizations concerned with international development.

The new awareness of the need to improve agriculture was reflected in many specific activities. The Development Assistance Committee of the Office of Economic Cooperation and Development met in Washington in July 1966 to consider special efforts to improve international food production. The President's Science Advisory Committee established a Panel on the World Food Supply which conducted a thoroughgoing study and presented its report, *The World Food Problem,* in May 1967 [Food Problem, 1967]. The U.S. Agency for International Development reshaped its organization and program by setting up, in February 1967, an Office of the War on Hunger to give special attention to agriculture, nutrition and family planning.

Efforts to establish or strengthen family planning activities were intensified in certain developing countries with especially critical food shortages. Budgets for family planning programs in the U.S. Agency for International Development not only were increased from $5 million in fiscal year 1967, to $35 million in

1968, and $50 million in 1969, but these funds were specifically earmarked by the Congress for this purpose.

It cannot be said that the food deficit in India in 1965 was unexpected. The agricultural production team sponsored by the Ford Foundation, in its report of April 1959 on *India's Food Crisis and Steps to Meet It* [Ford Foundation, 1959, 3, 3-4], stated that the team,

> . . . reaches the inescapable conclusion that an immediate and drastic increase in food production is India's primary problem of the next seven years. It points out that without food enough, India's hopes for improving human welfare, achieving social justice, and securing democracy will become almost impossible of attainment.

The team further stated:

> If India's food production increases no faster than present rates, *the gap between supplies and target will be 28 million tons by 1965-66.* This will be about 25 per cent shortfall in terms of need. *No conceivable programme of imports or rationing can meet a crisis of this magnitude.*

In spite of this stern warning by a team of able agriculturists looking specifically at India, and continuing evidence provided by the Food and Agriculture Organization of the United Nations of the steady decline in per capita food supplies in many developing nations, the problem of abundance of people and the inadequacy of food did not achieve true international recognition until 1966.

The special efforts initiated in 1966 and 1967 to mobilize resources for international agricultural improvement reflected a general assumption that this problem would persist through the turn of the century—and that it ranked with the search for peace as *the* priority item for cooperative international attention.

The Image of the World Food Problem, 1969

Within three years after the worldwide awakening to the prospect of extensive famines there emerged a spirit of cautious

optimism about near-term world food supplies. The record harvests of wheat and rice in South Asia and the rice bowl countries in 1967 and 1968 furnished assurance that the *immediate* world food crisis is not insurmountable. And the increased productivity of food grains in India, Pakistan, the Philippines and other countries of Asia furnished strong support for expectations that these countries could achieve approximate food grain self-sufficiency within a few years.

The rapid and apparently simple resolution of the world food supply emergency by the end of 1968 is causing decision-makers in developing nations, and some administrators of donor national and international organizations supporting development programs, again to oversimplify the task of agricultural development and to underestimate the complexities of the interacting components within that development.

A major task in forestalling this resurgence of complacency is the presentation of a realistic perspective of world agriculture to the U.S. public which is supersaturated with reports of agricultural surpluses and has developed such an apathy and antagonism toward foreign aid that the Congress, reflecting this attitude, reduced appropriations for the USAID program for fiscal 1969 to the record low level of $1.75 billion.

An article in the *New York Times* on U.S. agriculture [Fowler, 1968] stated, "Glut is a word that applies this year to the wheat, corn and soybean crops, three of the nation's basic and most valuable commodities." The *New York Times* review [Sept. 13, 1968] of the United Nations Food and Agriculture Organization annual report, *The State of Food and Agriculture, 1967* [FAO, 1967], pointed up the favorable trends in world food output, with a 6 percent rise in some developing countries as contrasted with an average world population increase of only 2.2 percent. The lengthy column covering the FAO summary, including the statement "The world food and agricultural situation is now in a state of transition and hope," was followed by a brief report headed "Danes Fear Grain Glut," which pointed out that the abundant grain harvest in 1968 threatened reduced prices to Danish farmers for their crops.

And the image of abundance continues to confront us. The financial page of the *New York Times* carried the headline

"World's Food Glut Strains Trade Relations" [Jones, 1969]. This article begins by stating, "Increasing world production of major food crops—a bright potential for feeding larger populations—is currently building up costly surpluses and straining international trade relations." The article ends with the statement:

> . . . the predictions of a few years ago that rising populations would bring widespread famine are no longer valid. Even in developing countries, according to authoritative reports, food grain production, as the result of increased emphasis on agriculture, is now growing as fast as their 2½ per cent annual birth rate.

It is difficult to maintain a sense of urgency, or to be worried about *Famine 1975!* [Paddock, 1967], in the face of such overly-optimistic assessments of future world food production. Periodic conferences are still being held to review the world food supply-population growth problem, but the issue now appears to be on the "back burner" and primarily of academic interest, rather than of continuing critical international concern. There is a general failure to recognize that the recent encounter was merely a skirmish in the continuing War on Hunger, that we were most fortunate in having the right sorts of ammunition handy, and that static solutions will not keep pace with dynamic new dimensions of the problem.

Reshaping Strategies for Agricultural Development

The increased productivity of wheat and rice in certain food deficit nations of Asia has bought additional time—perhaps a decade—during which production may be increased by further exploitation of the new agricultural practices. We shall then be faced again with the need to accelerate even more rapidly the rate of improvement in productivity to meet the world food needs of 1980 and beyond. As stated by President Robert S. McNamara of the World Bank in an address to the University of Notre Dame [McNamara, 1969, 19, 15-16], "Human dignity is severely threatened by the population explosion—more severely,

more completely, more certainly threatened than it has been by any catastrophe the world has yet endured." Mr. McNamara further stated:

> Wholesale famine is not inevitable. I am convinced that there is time to reverse the situation, if we will but use it. Only barely sufficient time. But time nevertheless.
>
> It is the time which has been given us by those who have created the revolution in agricultural technology: a revolution based on new seeds, hybrid strains, fertilizers, and the intensified use of natural resources.
>
> It is a revolution which already has increased the yields of food grains by more than 100% in parts of Southeast Asia, and which promises to boost yields by one-half ton per acre throughout Asia. It is a revolution which has expanded the number of acres sown with the new seeds from 200 in 1965 to 20,000,000 in 1968—and an estimated 34,000,000 in 1969—but which has yet to touch more than a small percentage of the rice and wheat-producing acreage of the world.
>
> If we will but speed the spread of this agricultural revolution—by adequate and properly administered technical and financial assistance to the developing countries—we can expect that for the next two decades the world's food supply will grow at a faster rate than its population.

In emphasizing the critical consequences of unchecked population growth, Mr. McNamara stated:

> There is no point whatever in being naively over-optimistic about a situation as full of peril as the population problem.
>
> But I am confident that application of the new technology will dramatically expand the rate of agricultural growth and will buy two decades of time—admittedly the barest minimum of time—required to cope with the population explosion, and reduce it to manageable proportions.

Whether the respite from the recent world food crisis extends for one decade or two, *there is little difference of opinion among those seriously concerned about the continuing rapid population growth with respect to the need for more effective pro-*

grams of family planning and for improved strategies for achieving sustained growth in food production and in agriculture generally in the developing nations.

The food-population problems are intermingled, but it is the purpose of this paper to assess some of the past experience in agricultural development, and particularly within agricultural technology, to identify opportunities for accelerating and sustaining agricultural growth.

Factors in Agricultural Growth

Much has been learned about economic development and the components of agricultural growth during more than 20 years of U.S. collaboration with the developing countries. However, an interesting feature of some recent in-depth analyses of agricultural development is the effective elucidation of the critical components—and then the obfuscation of such specific identities with the generalizations that "agricultural development and overall economic development are critically interdependent in the hungry countries," or "any lasting solution of nutritional problems depends on consumer purchasing power and thus on progress in the non-agricultural sectors of the economy." Such statements, the former from the *Report of the Panel on the World Food Supply* [Food Problem, 1967], and the latter from the FAO annual report on *The State of Food and Agriculture, 1967,* while basically correct, must not be allowed to justify continuation of past tendencies to dabble superficially in many things—or to concentrate on the seemingly simple factors—and to fail to come to grips with critical key elements of the agricultural problem.

We need not debate the desirability of well-rounded growth in the various sectors of the total economy, or the significance of agriculture versus industry. It is essential to treat the task of increasing food production and relevant agricultural development as a specific challenge and to avoid lumping this effort into broad or generalized programs of economic development. The building of a more productive agriculture must no longer be submerged under general concerns about rural social wel-

fare. The latter is an important but equally distinct and special problem.

Mosher [1966] identifies essential elements for agricultural development as (1) markets for products, (2) constantly changing technology, (3) local availability of supplies and equipment, (4) production incentives for farmers, and (5) transportation. He lists as "accelerators" (1) education for development, (2) production credit, (3) group action by farmers, (4) improving and expanding agricultural land, and (5) national planning.

There are of course divergent views about the relative significance of the different factors, but it is increasingly apparent that the real sophistication in planning for agricultural development lies in the strengthening of each of the individual components and then providing for their effective assembling or coordination. The "general practitioner" approach to agricultural improvement has not been particularly effective in U.S. technical assistance programs to date and our domestic experience in modernizing agriculture exemplifies the value of combining highly specialized competencies. Each of the pertinent elements must be given appropriate attention to ensure its excellence or adequacy for an essential, effective role in the agricultural growth process.

The Time for Technology

While we need not be concerned about the relative *importance* of the components of agricultural growth, we should be alert to the *timing* of their role. We have seen the result of many years of attempts to utilize *ill-suited* or *unsuited* agricultural technology in cooperative technical assistance programs in which primary attention was given to community development, extension systems, cooperatives, credit organizations or other factors. During the past three years we have had a most convincing demonstration of the significance of *well-suited* technology, designed specifically for tropical agriculture.

The dramatic short-run advance in agricultural production in Asia has been termed "The Green Revolution." The factors combining to bring about the greater food grain output in-

clude, (1) strong interest and support at top levels of the national governments; (2) greater incentives to farmers, including price supports and assurance of markets; (3) the availability of essential production inputs or supplies such as fertilizers, pesticides and machines; (4) more effective promotion or extension systems; and (5) new technology.

The "packages of practices" representing the new technology for wheat and rice production are generally recognized as *the* dominant force in generating the higher levels of productivity. The short-strawed, fertilizer-responsive, high-yielding wheat varieties which are nonsensitive to day length, together with the improved cultural practices, better water management, and more effective pest control, are the product of intensive research conducted cooperatively by the Ministry of Agriculture of the Government of Mexico and the Rockefeller Foundation since 1943. This new wheat production technology, developed under the high-altitude tropical and subtropical conditions in Mexico, had been tested extensively in trials initiated in the early 1960s in the Near East and South Asia countries, with cooperation from the Food and Agriculture Organization, and since 1963 in India and Pakistan [Krull, 1968].

The high-yielding rice varieties IR-8 and IR-5, and related production practices, are the product of similar intensive, multidisciplinary research by the International Rice Research Institute which was established through cooperative support by the Ford and Rockefeller foundations and the Government of the Philippines in 1962.

The "new technology" inputs were fortunately available when the decisions were reached by the several nations in Asia to undertake aggressive action to boost agricultural productivity. Without this essential component the world food problem would no doubt still be in the forefront of international concerns.

The yield-increasing thrust of the new wheat and rice production technology not only has supplied the cutting edge for agricultural development but also has enhanced the significance of the related growth components. Extension programs have

little value unless there is something worthwhile to extend; credit and marketing systems have greater relevance when production levels become rewarding for investments in commercial agriculture; and the supplies of fertilizers, pesticides and machines are meaningful when their purchase and use pays off in greater productivity.

From a critical analysis of factors in rural progress in India Dr. John W. Mellor [1968, 363-64], Professor of Agricultural Economics at Cornell University, concluded:

> The most telling criticism of Indian agricultural development policy is that a key deficiency—lack of an effective organization to produce a flow of highly profitable innovations suited to Indian conditions—was not recognized at the beginning. The reasons for this error are obvious enough. There was an existing research program of substantial proportions which claimed to have a large body of proven results ready for application on farms. The error was not in under-rating the importance of improved technologies but in overestimating the productivity and applicability of what was at hand. . . .
>
> . . . The research problem came increasingly to be realized in the second and third plan periods. The advantage of hindsight suggests that at least five years and possibly ten could have been saved if this problem had been more fully understood and tackled initially. In commencing an integrated research program, the effort must necessarily be small for lack of personnel both at the administrative and technical side and because movement must be made step by step in order to integrate adequately with other institutions and problems. Thus, an effort in this direction at the beginning of the first plan would not have detracted significantly from other efforts, such as Community Development, and yet as it gradually grew and achieved success it would have rapidly increased the productivity of other resources in the agricultural development process.
>
> The obvious lesson is that the first step in an agricultural development program should be initiation of a substantial, highly integrated research program, directly connected to farm problems at one end and to basic research and foreign efforts at the other.

"Second Generation" Problems from the Green Revolution

The massive output of food grains in Asia in the past two years has drawn attention to a wide range of companion problems in the agricultural sector of participating nations. These have been identified by Blume [1968], Dalrymple [1969], Wharton [1969a], Eicher [1969], Flores [1969] and others. Most of these problems are not new and would have been minimal if attention had been given in national development programs to the magnitude of infrastructure and services required for levels of production approaching national needs.

The adjustments required by a rapidly changing and growing agriculture vary from country to country. Most of the problems are nation-specific, if not location-specific, and will require studies which take into account social and political factors as well as physical environments.

The widespread publicity given to the "Mexican wheats" and "miracle rices" has created the impression that the new technology by itself has been responsible for the food grain production increases. There is a false assumption also that the "biological research" is well in hand and that further new technology inputs can be obtained almost instantaneously and relatively simply through a few research centers concerned with international tropical agriculture. These judgments fail to recognize that the recent breakthroughs in increased wheat and rice productivity represent extremely unusual occurrences and that advances of such magnitude in yield potential cannot be generated at will. Also, the *sustainable productivity* under various cropping conditions cannot be assessed on the basis of one or two seasons but must be judged after sufficient time has elapsed for the confrontation between exogenous plant materials and indigenous diseases and pests.

Established crop improvement procedures usually entail a minimum of three years of widespread testing of a new crop variety before it is released to growers. In the case of the improved rice varieties, particularly, they were moved into wide-scale production in some countries after only one season of observation trials in a few locations. The heavy destruction of plantings of IR-8 in a number of countries in 1968 by virus,

bacterial or fungus diseases emphasizes the importance not only of preliminary testing but also of follow-up protective research. The susceptibility of the Mexican wheats to certain races of rust which exist in India, Pakistan and Turkey also is well-recognized by plant breeders and pathologists, including the research workers who developed them.

In addition to the urgent need for *protective research to maintain the advances* of the wheat and rice production technology, there is need for further adaptive research to exploit the new yield potentials by developing more precise "packages of practices" for additional growing areas.

Effective research to bring about continuing incremental increases in productivity must be undertaken, with integrated attention to the plant sciences, soil science, and to pest and disease control factors which combine in achieving new high-yield capabilities. Changes in the characteristics of the varieties such as for grain color of wheat, or cooking and eating quality of rice will also demand adaptive research attention.

An equally important consideration is *research to increase diversification* and to broaden the base of agricultural production in the various developing nations. This requires attention not only to the food grains but to other food crops, to oil seeds, fiber plants and other industrial crops, to livestock improvement, to land and irrigation development and the related soil and water management, as well as to processing and product quality research.

Non-biological dimensions of the problems requiring research also can be identified. It is fully apparent that past attention given to the development of infrastructure, particularly to transport, storage and processing facilities, was not geared to the *expanding* requirements of the developing nations, to enable the handling of the quantities of agricultural products needed for self-sufficiency for a growing population.

Measures taken to stimulate and intensify agricultural production, including price supports and other incentives to producers, and the assurance of markets, will have to be reviewed promptly to keep future production in reasonable balance with market opportunities. The expectations of certain countries that their excess grain production will find ready acceptance in

foreign trade channels have been short-lived and must be reconsidered realistically to avoid overcommitment of investments by farmers in special purpose machines, or by governments in price support programs for particular crops.

Research in farm management and on production costs for different types or systems of farming, including studies of import substitution, will be essential to guide national agricultural diversification programs. And research in economics and the social sciences must be strengthened to minimize problems of income disparity in rural areas and to temper the social impact of agricultural development and change not only in rural communities but also in acceleration of urbanization as national development proceeds.

Building National Research Capabilities

Only a few of the many interrelated problems of continuous agricultural growth and development can be assessed and resolved from a general or international perspective. Most of them will require intimate knowledge of localized conditions, whether we consider the soils and climates of various cropping regions or the ethnic and social features of specific communities. It is increasingly important, therefore, that each developing nation build its own research capability, not only to supply new biological inputs but also to furnish the guidance and the understanding of the multiplicity of interacting factors associated with sustained economic development.

From U.S. experience we can conclude that the provision of agricultural science from external sources must be a temporary expedient and that sustained growth really begins when a nation establishes its indigenous research competence and organizations. This has special relevance at the present time since countries which have recently gained their political independence should not in this day and age be expected to be content with colonial status in science and technology.

Specialized international research centers or institutes have been, and will probably continue to be, primarily resource centers and distribution points for innovations which will require

adaptation to specific local environments to extract maximum benefits from basic potentials. These centers will, therefore, play an important but partial and transitional role in world agriculture as the essential national science capabilities are developed in each country.

Many international technical assistance programs have been concerned with some aspect of institution building. Few, however, have been directed toward the formation of effective national systems of agricultural research. As stated by Dr. T. W. Schultz [1964, 201] of the University of Chicago:

> Although our government has been actively engaged in technical assistance in agriculture throughout Latin America for two decades, the sad truth is that not a single first-class agricultural research center has been developed as a consequence of these activities. Mexico has done well, but not because of any technical assistance from the U.S. Government. The funds and talent provided by The Rockefeller Foundation have, however, played a part in the Mexican advance. Japan has done exceedingly well on her own. But throughout South Asia, where we have both public and private commitments to assist agriculture, with few exceptions new agricultural research has been neglected. The new research to develop superior wheat, corn, and grain sorghum varieties in India and the recently established International Rice Research Institute in the Philippines are among the exceptions.

Some may take issue with the above judgment but the fact remains that we still have lamentably few effective research centers for agriculture in the developing nations today, five years after Schultz' statement. The limited attention to the building of *national systems* for agricultural science not only reflects the lack of awareness of such a need on the part of most developing nations but also, and more significantly, a continuing lack of concern on the part of many donor organizations and nations.

The continuous increase in productivity of U.S. agriculture, permitting the doubling and the redoubling of yields of many crops during the past three decades, has come from a highly integrated system of institutionalized agricultural science. But our technical assistance programs to date have emphasized primarily attempts to transfer the fruits of this system, or to trans-

plant only selected components of the institutions within the system. And while the introduced wheat and rice production technology dramatically illustrates the potentials from well-designed research it will contribute little to continuing- and longer-term growth inputs unless these cooperative emergency projects are built into effective national research organizations.

Perhaps the most certain feature about the building of national systems for agricultural research is that neither the significance nor the processes are well understood by the majority of those working in international agricultural development. It is increasingly apparent that those of us concerned with the problem have done a very poor job of communicating the relevance of institutionalized agricultural science, its structure, its functions, and the procedures through which we can strengthen or establish this essential national resource.

One principal difficulty is that those participating in agricultural development programs operate from widely divergent bases of knowledge and experience. They come from distinct scientific or professional disciplines—economics, social sciences or the natural sciences. The variation may be within the profession, as a research scientist, teacher, or extension agent; or it may be in the scope of operational experience, at the local, state, national, or international level. Regardless of the specific backgrounds from which we operate, we find it difficult to perceive the scope of the task of developing effective agricultural research institutions into national systems in the developing countries because we have such an incomplete and fractionated concept of such systems.

This paper reviews some pertinent features or components of effective agricultural research programs, with special reference to U.S. experience, and their interrelationships in a functioning national system. In considering national systems of research we should keep in mind the broad scope of disciplines or problem areas, including those in the natural and social sciences and in economics. But for illustrative purposes in this paper, special attention is given to research experience in crop improvement because (1) this has special relevance to the recent progress in evolving packages of practices for increasing wheat and rice productivity, and (2) the local, national, and international ex-

periences in crop improvement illustrate how research in other fields or disciplines may be, or is, conducted in similarly integrated cooperative efforts.

If effective national systems of research are to be developed, their requirements must be understood both by officials in each country and by officials of technical assistance agencies. This paper is written with the latter group primarily in mind but may be useful to the former group as well.

Chapter II

THE AGRICULTURAL RESEARCH BASE OF THE UNITED STATES

An understanding of the institutional structure for agricultural research in the United States is particularly essential for U.S. agriculturists who would furnish guidance for organization of national research systems in developing countries. The major components in the U.S. system are (1) the state agricultural experiment stations, (2) the U.S. Department of Agriculture research, and (3) the research of private industries or organizations.

There is a general tendency to identify specific units such as a state experiment station, a land grant college, a commodity research institute, or an agricultural research project of the USDA, and attempt to establish a counterpart of one or more of these units in cooperating developing nations with the expectation that they will supply *the* effective technological input. Experience has demonstrated that this approach results at best in only the installation of that small segment of the system and does not build an effective national research infrastructure.

The State Agricultural Experiment Stations

Many of the present generation of agricultural specialists in the U.S. tend to regard the land grant institutions with their triumvirate function of education, research and extension as a unified and systematized approach to agricultural improvement which has considerable transferability—from the standpoint of form as well as function—to the developing nations. How valid

is that judgment? To help answer that question, with respect to research, it may be well to look at the outreach or potential impact of a single state agricultural experiment station. It would be worthwhile also to review the evolution and emergence of the research component of the land grant college and to recognize that considerable special effort was required to establish this part of the triumvirate.

The national impact of state agricultural experiment stations stems from the existence of one or more such institutions in each of the states, and their interrelationships or cooperation on regional problems. The individual state experiment station has a limited geographical coverage, with substantial statewide influence but only a modest *direct* effect on agricultural growth and development nationally. The Cornell experiment station has little direct influence on improvement of citrus production in Florida, California, or Texas. The Florida experiment station has little to contribute to the apple growers of the Yakima Valley or to the diversified irrigated agriculture of the Columbia Basin in Washington. The Iowa agricultural experiment station contributes little directly to the cotton growers in the southern states or in California, Arizona and New Mexico.

The limited direct national impact of a given experiment station does not minimize the importance of the research conducted by these stations. Some of the most significant basic and background research has emerged from the excellent academic and scholarly environments of these institutions. Also, the continuous addition of incremental research of graduate students supplies an invaluable cumulative knowledge base. The interchange of ideas and material through participation in regional and national research programs also broadens the scope of influence of a given agricultural experiment station. But those elements by themselves do not automatically combine into the cohesive and systematized problem-oriented, multidisciplinary research necessary for national impact.

The most significant national and international dimension of the land grant institutions comes from the teaching or education component—particularly graduate teaching. But while individual graduate students furnish a linkage to many sections of the United States, and to many agricultural regions through-

out the world, they may not necessarily convey or transmit any significant segment of problem-oriented research from the individual experiment stations of the universities where they study.

The Evolution of Concepts of Experimentation

We frequently fail to recognize that the agricultural experiment stations developed as distinct—and somewhat separate—components of the land grant institutions. Their partnership role in the triumvirate is marked by a long and somewhat tortuous effort to achieve strength and identity, first in relation to the educational component of each university and later with respect to extension. This is well recorded in *State Agricultural Experiment Stations: A History of Research Policy and Procedure* [USDA, 1962], issued in observance of the USDA-Land Grant College centennials. This publication traces the evolution of research for agricultural improvement from the concept of experimentation by the Franciscan friar Roger Bacon in the 13th century, through the systematic studies guiding agricultural development in England and the American Colonies during the 1600s to the present decade.

The concept of experimentation or "the making of scientific inquiry and the systematic probing of practice" was fostered in the early years of the U.S. by the state, county or city Societies for the Promotion of Agriculture which numbered more than 900 by the year 1860, two years before the Acts of Congress creating the U.S. Department of Agriculture and the Land Grant Colleges were signed.

The systematic development of agricultural experimentation in Scotland and in Saxony stimulated a few Americans in the early 1850s to develop agricultural research stations in this country. Samuel W. Johnson, who studied under the German chemist Justus von Liebig and joined the Yale Analytical Laboratory in 1850, is credited with having "spent a lifetime searching for the most effective ways to institutionalize research in agriculture" [USDA, 1962, 14]. He helped to pioneer the concept of an experiment station as a center with laboratories, a library, greenhouses, and test plots, and with a topnotch scientist to serve as the director or executive officer.

Although the idea of institutionalizing agricultural research through a well-endowed state agricultural college with an experimental farm—"with teachers for diffusing knowledge and researchers for enlarging it"—traces back to 1850, only five of the land grant colleges had established experiment stations prior to the passage of the Hatch Act in 1887. These were the Michigan Agricultural College in 1862, the universities of California in 1880, Tennessee in 1882, Wisconsin in 1883, and Kentucky in 1885 [USDA, 1962, 29]. Most of the remaining states either were not interested in developing experiment stations or were willing to see these established separately from the agricultural colleges.

Experiment Stations as Distinct Entities

Throughout the early history of the development of the state agricultural experiment stations, there was continuing uncertainty about the relationship of the research stations to the land grant colleges and to the U.S. Department of Agriculture. Of special concern was the acquisition of federal funding through the Department of Agriculture for support of experiment stations in the states, associated with the colleges, free from excessive domination or direction by the federal Commissioner of Agriculture. The Hatch Act of March 2, 1887 successfully resolved this issue and provided for a high degree of autonomy by the individual states in designing and conducting research.

The succession of legislation furnishing support for the establishment and strengthening of the agricultural experiment stations clearly recognizes the stations as distinct entities in the land grant colleges, as follows:

(1) the Hatch Act of 1887 to establish agricultural experiment stations in connection with the colleges established in the several states under the provisions of the Morrill Act of July 2, 1862, and of the acts supplementary thereto;

(2) the Adams Act of 1906 to provide for an increased annual appropriation for agricultural experiment stations and regulating the expenditure thereof;

(3) the Purcell Act of 1925 to authorize the more complete endowment of agricultural experiment stations, and for other purposes;

(4) the Bankhead-Jones Act of 1935 to provide for research into basic laws and principles relating to agriculture and to provide for the further development of cooperative agricultural extension work and more complete endowment and support of land grant colleges;

(5) the amendment of the Bankhead-Jones Act and the Agricultural Marketing Act of 1946 to provide for further research into basic laws and principles relating to agriculture and to improve and facilitate the marketing and distribution of agricultural products;

(6) the Act of 1955 to consolidate the Hatch Act of 1887 and laws supplementary thereto relating to the appropriations of federal funds for the support of agricultural experiment stations in the states, and in Alaska, Hawaii and Puerto Rico.

Relations Between Scientists and Educators

A continuing controversy, or at least competition, between the academicians and scientists is reflected in the development of the Land Grant College Association which was formed in 1887. For many years the presidents of the colleges and the directors of the experiment stations were in conflict over the question of whether to organize the Association into two sections, one on college work and one on station work. A major concern of the experiment station directors was to provide for the maximum interchange of ideas between scientists, across discipline lines, and for "unobstructed opportunity for the prosecution of research in agriculture."

In 1889 many of those attending the Association meeting did not share the special concern about research "if only because their diversified collegiate duties of a non-research nature, particularly in the classroom, prevented them from developing a professional preoccupation with research" [USDA, 1962, 69]. It was not until 1903 that the Association was organized into two Sections, one on college work admitting only the presidents, and the other on station work, primarily for the directors but also admitting other station officers.

The early years of the development of the college-experiment station relationship were marked by uncertainty with respect to the "double duty" of the teacher and investigator. William A. Henry, who had been Director of the Wisconsin Agricultural

Experiment Station from its establishment in 1883, in his address as President of the Land Grant College Association in 1893, stated, "No man, however able, is properly prepared to do any considerable amount of classroom work, then conduct investigations of the grade that our experiment stations must call for in the future" [USDA, 1962, 74]. The customary system at that time was for the professors to carry the teaching load, with assistants—usually recent graduates—handling the experiment station responsibilities. President Henry suggested that "if we cannot have men of first grade in both the station and college, let us have them in the station and turn over our general instruction to the assistants" [USDA, 1962, 74]. He suggested, however, that "investigators of first grade" should not be separated entirely from the teaching function but should be brought to the classroom for one hour a day for one term in the year to impart instruction of high grade and thus furnish the "final polish" to graduating seniors.

The Nature and Quality of Research

The conflict between the educators and researchers extended also into the question of the scientific excellence of research. Dr. Wilbur Atwater, the first Director of the Office of Experiment Stations, outlined the principles for effective agricultural experimentation, to include (1) the selection for study of only a few problems, (2) planning for each problem a program of painstaking experiments, (3) persistence in each program to complete it and establish a conclusion, and (4) the operation of a station as a scientific institution at all times [USDA, 1962, 83]. According to the record, however, the first generation of experiment station workers following passage of the Hatch Act were not able to concentrate on "original researches" since the attitude of "practical minded men"—those untrained in advanced scientific discipline—was destined to predominate for the balance of the century.

The tendency to concentrate on shallow researches or demonstrations, as contrasted with effective scientific inquiry, plagued the experiment station development for the decade following the passage of the Hatch Act. Whitman Jordan, Director of the Geneva Experiment Station, stated in 1897 that persistent fail-

ure to comprehend the distinctions between "instruction" and "inquiry" characterized the attitude of most land grant personnel. He blamed this on the dual responsibility for research and teaching which seriously sapped the energy and time of the investigators, so that the stations were obtaining an inadequate return from the Hatch Act expenditures. He protested that the types of investigations actually attempted did not aim in many instances to discover new truths, but to illustrate the application of old truths, which he charged was an instructional effort rather than one of real inquiry.

Director Isaac P. Roberts of the Cornell Experiment Station argued, on the other hand, that the stations should function primarily as diffusers of improved methods and only secondarily as investigating agencies. His concept was that the stations should concentrate on rural instruction until the farming community had fully exploited the technological capabilities of the information already available in the 1890s. There was a widespread feeling among experiment station personnel—the agricultural scientists—that the colleges were using the farmer-oriented demonstrations primarily to gain favor of the rural communities and thereby to ensure sympathetic support for college budgets through the state legislatures.

Research and Extension

In addition to the continuing differences with the college-oriented leadership of the land grant institutions over "the erosive teaching functions" and the quality of research the experiment stations were confronted with the gradual diversion of Hatch Act funds for non-research purposes including printing, correspondence, administration, and general business operations of the station. The funds also were being used increasingly for the development of extension activities. This reached sufficiently serious proportions to prompt a letter from Director A. C. True of the Office of Experiment Stations on February 25, 1909 [USDA, 1962, 113], calling for a restriction of such diversions and stating, "Beginning with July 1, 1909, it will be expected that all charges for extension work and printing of compilations will be eliminated from the Hatch fund account."

The passage of the Smith-Lever Act in 1914 providing funds for the extension service helped to resolve these difficulties.

Experiment Stations in the National System

One of the more significant features of the U.S. state agricultural experiment station evolution is the recognition that:

> . . . Research ought not to be regarded merely from the local standpoint. The experiment stations constitute a national system and they bear an intimate relation to the Federal Department of Agriculture. Correlation of their efforts is essential to economy of effort and efficient progress. After it has been effected, there will still remain sufficient individual opportunity and institutional initiative for self-expression [USDA, 1962, 126].

The above statement by Dr. Edwin W. Allen, the Chief of the Office of Experiment Stations and the Assistant Director of Scientific Work in the Department of Agriculture in 1929, elucidates the philosophy of the effective partnership of the state agricultural experiment stations and the U.S. Department of Agriculture in a national system of institutionalized agricultural science. There have been many imperfections in this relationship, with recurrent stresses and discords, but it has nevertheless furnished a hard core of service-oriented, cooperative research for many decades.

The State Experiment Stations and International Agricultural Development

The foregoing review focuses on only a few of the specific growing pains as the experiment stations evolved within the state land grant institutions. There are some salient points to ponder as we draw upon this U.S. experience to furnish guidance in strengthening the agricultural research infrastructure in developing nations.

There are still widely divergent viewpoints with respect to the degree of emphasis and priority for (1) education, (2) farm demonstrations or extension, or (3) research in the upgrading or modernization of agriculture. Regardless of the relative emphasis, *it is evident from the history of the evolution of the experi-*

ment stations within the U.S. land grant colleges and universities, and from the experience to date in U.S. technical assistance programs, that the agricultural research component will not be built into the resource structures of the developing nations unless there is a concerted effort to bring this about.

We should not expect research capabilities to emerge automatically from cooperative programs concentrated largely, or entirely, on building educational institutions or extension programs. It is doubtful also whether we can generate any substantial measure of new science and technology as a residue from projects conducted by persons concerned primarily with education and extension functions.

The individual developing nations have different requirements to be met by their vocational schools and colleges of agriculture. These should be fostered and developed as needed, but the building of a national capability in agricultural research should not be submerged in an amorphous education-research-extension complex merely because this form of organization has been useful as a *part* of the national system in recent decades in the United States.

Evaluation of the research contributions of the U.S. land grant universities would be incomplete without some special attention to trends during the past 15 years, particularly during the "post-Sputnik" era. The drive for recognition by the land grant colleges as true universities has tended to place colleges of agriculture in these institutions in subordinate roles. The increasing availability of research funds from numerous federal agencies has fostered realignments of teaching and research organizations related to agriculture in the land grant universities, with greater emphasis on basic—non-practical—studies. The resulting teaching-research supported by what has been termed, unfortunately, "the soft federal monies" has only limited value in either training or in research application for the developing nations. Moreover, the concept that applied research lacks dignity and sophistication for both the individual and the university has narrowed the field of institutions which can serve effectively the problem-oriented requirements of developing nations whose needs are more akin to those of U.S. agriculture in the 1920-40 period.

There is a widespread assumption that the land grant universities represent the prime resource for U.S. technical assistance in improving agriculture in the developing nations. Although a growing portion of the research in the U.S. land grant universities may now be somewhat ill-suited to the specific needs of the developing nations, the strong emphasis through earlier years on research for development of U.S. agriculture and the interraction, not only between disciplines but also between the functions of research, teaching and extension, have much to offer international agricultural development. It is important to recognize, however, that it is this earlier development-oriented experience rather than the current emphasis in many of these institutions which has relevance and value.

The Research of the U.S. Department of Agriculture

Agricultural research at the federal government level traces to the interest of early national leaders, including George Washington and Thomas Jefferson, and their role in the formation of Agricultural Societies. A pioneer federal government activity was the introduction of plants from abroad, handled by the Patent Office of the Department of Interior. The Agricultural Division of the Patent Office, which in the early 1850s had the professional competence of an entomologist and a chemist, formed the nucleus for the development of the Department of Agriculture in 1862 under a commissioner of non-Cabinet rank. The act of May 15, 1862, establishing the U.S. Department of Agriculture, directed the Department "to acquire . . . useful information on subjects connected with agriculture in the most general and comprehensive sense of that word . . ." [USDA, 1962, 26]. This broad authorization has enabled the Department to participate effectively in a wide range of research activities of national concern.

Federal Research Stations and Laboratories

When it was evident that the westward migration of agriculture in the U.S. required additional guidance, particularly for

farming systems in dry land and irrigated regions, a number of specialized research centers were established by the USDA. These stations, set up near the beginning of this century, included the U.S. Northern Great Plains Field Station at Mandan, North Dakota; and the U.S. Southern Great Plains Field Station at Woodward, Oklahoma. Smaller stations were established at Newell, South Dakota; Sheridan, Wyoming; Akron, Colorado; Sacaton, Arizona; Mesa, California; and at other locations in the western states.

These dry land and irrigation field stations made significant contributions to the selection of crops, of crop varieties, and to cultivation practices, including conservation and management of soils and water. The stations were essentially demonstration farms, utilizing the best known practices from farmer experience and from the relatively limited research on crops and soils.

In the mid-1940s, in recognition of the fact that research on soil fertility and moisture management is highly location specific, since it ties to soil types and rainfall patterns of given regions, initiatives were taken by the USDA to transfer many of the federal dry land and irrigation facilities to the state agricultural experiment stations. Federal funds and staff resources were shifted to a more intensive program of background research, conducted increasingly at the main state agricultural experiment station headquarters. A decade later, however, there was a resurgence of demand on the part of farmers and ranchers in the western states for more effective guidance in soil management and water use, and new legislation was passed by the Congress providing for the establishment of additional soil and water research centers.

Specialized U.S. regional laboratories set up under support of the Bankhead-Jones Act of 1935 [USDA, 1962, 223] reflected (1) the recognized need for greater fundamental or basic research in selected problem fields, and (2) the importance of joint attention to such problems by scientists from different disciplines. Upon recommendation of the states within the region, and with federal funding, U.S. regional laboratories were established for research on vegetables at Charleston, South Carolina; pastures at State College, Pennsylvania; plants, soils and nutrition at Ithaca, New York; soybeans at Urbana, Illinois;

poultry at East Lansing, Michigan; sheep breeding at Boise, Idaho; and soil salinity at Riverside, California.

The Bankhead-Jones laboratories were established in the late 1930s. The outbreak of World War II caused a decided shift of attention away from fundamental studies toward production-oriented research to meet agricultural requirements for the war effort. As a result, the operating budgets were restricted from the start and while the laboratories have made many useful contributions their impact has been affected adversely by those early lean budget years.

The four U.S. regional "utilization research" laboratories established about 1940 at Peoria, Illinois; Wyndmoor, Pennsylvania; New Orleans, Louisiana; and Albany, California, were set up to expand uses for agricultural products, not only for commodities in surplus but also to extend end uses for products and residues. Although these laboratories also were set up during the early years of World War II, they have continued to play a prominent role in national agricultural research programs.

The role of the specialized field stations and laboratories of the USDA has been diminished or modified as research capability was strengthened in the state agricultural experiment stations and their substations. This has not meant a decrease in the activities of the USDA since there are continuous demands by agricultural groups for research on specialized problems and these have resulted in the establishing of new federally-supported research centers such as the Boll Weevil Research Laboratory at Brookings, South Dakota; the soil and water research centers mentioned previously, and others.

Federal-State Relationships

The role of the USDA in the nationwide research system is highly flexible. The lack of a hard and fast distinction of federal versus state responsibilities is expressed in the statement by the special commission appointed in 1906 to determine,

> . . . the organization and policy that in the opinion of the commission should prevail in the expenditure of public money provided for scientific experimentation and research in the interests

of agriculture, to the end that such funds shall be applied in the most economical, efficient, and worthy manner in the production of results of permanent value [USDA, 1962, 124].

Of particular relevance to our assessment of the institutional structure of developing countries, especially those with unresolved questions about state or central government functions, is the following:

> There should be a clearer definition of the relative fields of work of the United States Department of Agriculture and the [state] experiment stations. The dominance of the stations within their respective fields should be preserved and their growth fostered, as agencies for the investigation of local questions and of the more individual scientific problems. The Federal agency, on the other hand, should cultivate the almost limitless field offered by questions having national or interstate relations, and by those broad scientific problems requiring heavy expenditures, elaborate equipment, long continued study, and the correlation of the results of many investigators, which efforts are usually beyond the means of an individual station. On many questions the harmonious cooperation of the two agencies is essential to the highest efficiency of effort.
>
> Any research agency charged with a single main line of investigation should be so organized that it may employ within itself all necessary processes in any branch of science. The cooperation of any or all of the departments of an experiment station on a single problem, when necessary, should be a fundamental requirement [USDA, 1962, 125].

This broad base for application of federal and state resources to research on problems of national, regional, or local concern, together with the recognition of the need for interdisciplinary approaches, as stated in 1906, has been an important factor in U.S. agricultural research for more than half a century.

The importance of a strong federal and state linkage in agricultural development was pointed up by then-President Elmer Ellis of the University of Missouri in addressing the International Rural Development Conference in July 1964:

> I have often reflected upon the curious local, state and national orientation of these [land grant] colleges and universities. They

are in every sense state schools which are woven into the warp and woof of each state's culture. Yet nearly all of them came into being because of an act passed by the National Congress. Moreover, many of the Land-Grant schools would never have survived those tumultuous early years without the support of that national land grant. State appropriations for state universities operations did not begin until the 1870's. Federal monies have always been a major part of the budgets of these state institutions. There are many good reasons for this federal-state partnership which has evolved. The benefits of agricultural research very seldom stop at the state boundary. There is no such thing as a Missouri vaccine for hog cholera [Ellis, 1964, 7-8].

The relations between the USDA and the states, while generally progressive and forward moving, have not been totally free from occasional stresses. The periods of 1903-1906, 1930-32, and 1953-58 have been recognized as eras of particular concern. Usually these were precipitated by shifts in emphasis or changes in organization.

One continuing disruptive factor in the relationship has been the degree of direction or dominance of the state experiment stations by the USDA in the administration of the Hatch Act and other federal grant funds. In 1894, for example, Secretary J. Sterling Morton noted that he had no control over the expenditure of the Hatch Act funds and deleted this item from his budget request for 1895. After some clarification of the type of reporting to be furnished by the states the item was restored [USDA, 1962, 91].

Similarly, in 1905, there was a discussion before the Congress in which a committee representing the state stations and Secretary James Wilson of the Department participated, reviewing the question of the magnitude of appropriations for federal grants to the states. This hearing reflected the growing concern of the state experiment stations about the increasing involvement of the USDA in research—with additional federal field stations established in the states—and the growth of the Departmental scientific staff of full-time research specialists with no teaching duties, which in 1904 substantially outnumbered the nationwide total of state station workers. It was pointed out that the Bureau of Plant Industry in 1904 operated on a budget

larger than the total Hatch Act appropriation to all the states.

In spite of the inevitable competition and conflicts, which have persisted to the present day, the general philosophy of the USDA has been to furnish guidance without excessive direction in the administration of the Hatch Act and other grant funds, and to participate cooperatively and provide coordinating services in regional research programs.

The nature and extent of federal participation in research for U.S. agricultural development has varied among specialized fields, but it has been extensive, both with respect to problems and geographically. The federal role has been prominent in certain areas such as research in utilization of agricultural products. There has been close cooperation between the USDA and the states in soil classification, in soil and water management and in conservation. A substantial part of the research on cropping practices is handled by the state experiment stations and their branch stations since such research is highly location-specific, depending not only on soil types but also on rainfall, temperatures, and other climatic factors.

In many instances the USDA has furnished specialized facilities or taken the initiative in establishing new cooperative research activities. The laboratory at Beltsville for the application of atomic energy in agricultural research, including the use of radioisotopes in soil and plant nutrition investigations, is one example. Another is the development of the Division of Weed Investigations in the early 1950s, providing for the joint and coordinated efforts of federal, state and private industry scientists in the development of herbicides and other methods for weed control.

Coordinated Regional Research

The Adams Act in 1906 established the U.S. Government policy that federal aid should join state aid in subsidizing scientific research in the state stations [USDA, 1962, 221]. This Act endorsed the idea of research of the highest quality and an administrative policy fostering local initiative with federal assistance. The Purnell Act of 1925 increased the federal grants to each state and broadened the field of research to include eco-

nomic and sociological investigations [USDA, 1962, 222]. Federal and state administrators utilized this additional support to initiate and strengthen cooperative research in a number of fields of broad concern.

One such regional project which has had an exceptional "pattern making" influence on agricultural research nationally and internationally was the successful exploitation of the phenomenon of hybrid vigor to produce spectacular increases in yield of corn in the 1930s, one of the significant milestones in the application of science and technology to agricultural growth.

Many plant geneticists contributed as individuals to our basic understanding of hybrid vigor, but Dr. H. K. Hayes, Professor Emeritus of the Division of Agronomy and Plant Genetics of the University of Minnesota, one of the principal early participating scientists, has stated [Hayes, 1963] that the real impetus for the practical development of hybrid corn in the U.S. came from the establishment, in 1925, of the cooperative research program of the corn belt state experiment stations and the USDA under the Purnell Act. This program, under the coordinating leadership of Dr. F. D. Richey of the USDA and with federal and state research workers participating, fostered the exchange of materials and ideas, the planning of uniform experiments that furnished information from many locations in a given year, and the prompt availability of data or experimental results to all cooperators.

Adaptive Research

The cooperative federal-state corn improvement program initiated in 1925 produced a number of hybrids suited for growing in the corn belt by the early 1930s. Ten years later, however, it was fully apparent that (1) the outstanding hybrids developed for the corn belt were not suited for growing in the southern or southeastern U.S., and (2) the coordinated research organization set up to serve the corn belt area could not effectively do the research job for the southern region. A separate regional organization was established in 1945, again under the leadership of Dr. Richey who made his headquarters at the

Tennessee Agricultural Experiment Station. (Dr. Richey had served as Chief of the Bureau of Plant Industry from 1934-38, after which time he went into private business before rejoining the USDA staff in 1945.) In addition to Dr. Richey, the USDA furnished full-time corn breeders in North Carolina, Georgia, Mississippi and Louisiana to work with their state counterparts in the southern region.

The experience in the transfer of the benefits of hybrid corn over the relatively short distance from Iowa to North Carolina and Georgia is relevant to the problem of effective infusion of new technology in international agricultural development. It provides a prime example of the importance of "adaptive research" to fit new technological advances to specific cropping environments. Even though materials or practices may be roughly suited to a given region it is the more precise fitting of potentials to specific locations that brings about maximum productivity.

Interdisciplinary Research for New Packages of Practices

The second special feature of the cooperative program to develop adapted corn hybrids for the southern states was the complementary program of interdisciplinary research to produce an effective "package of practices" to boost corn yields. This cooperative project, initiated by the USDA and the North Carolina Agricultural Experiment Station and in which other states later participated, gave concurrent attention to the selection of adapted hybrids, the plant populations per acre, and the manipulation of soil fertility to produce maximum yields under different soil and climatic conditions. Such joint attention by plant breeders, agronomists, and soil scientists was not common prior to 1945, but it has become one of the main features of modern agricultural science, both nationally and internationally.

In U.S. agricultural practice the utilization of new technology as combinations or interactions of multiple improvements is commonplace and receives no special attention. In international technical assistance programs this approach has been restrained in many cases by the assumption that farmers follow-

ing simple practices would find it difficult to accept or adopt more than one or two changes at a time. Also, because of the lack of indigenous research designed specifically for conditions in the developing nations, there has been a dearth of innovations to be combined.

The Ford Foundation team in its recommendations on the improvement of food production in India in 1959, emphasized the importance of "effective combinations" of improvements. As stated in the report:

> A few improved practices can be effective if adopted singly, but the full benefit from most improvements can be obtained *only* if they are adopted in combinations suitable for specific soil and climatic conditions. Sufficient fertilizers, improved seed, pesticides, proper soil and water management practices—all of these, while important in themselves, can be *fully effective only if adopted in combination with each other* [Ford Foundation, 1959, 18].

The application of new technology for wheat and rice production in Asia since 1965 has essentially put to work internationally the concepts and understandings about combinations of practices which have been common to U.S. agriculture for more than 20 years.

Protective Research

A major contribution of the U.S. national system of agricultural science and technology is the protection provided to the American farmer, the agricultural industry—and consumers—against serious losses from diseases, pests or environmental hazards. Crop plants have been bred and selected for tolerance to harsh environments including drought, frosts, or high temperatures. And constant battles are waged against new virulent forms of diseases or destructive insect pests of plants and animals. These, however, are usually not nationwide but take the form of regional skirmishes of short duration so the remedial research is seldom generally recognized or fully appreciated.

The following one-time serious threats which were systematically brought under control through accelerated research proj-

ects supported by special federal appropriations—and conducted jointly by scientists of the USDA and research personnel of the experiment stations of the states in which the particular threat or hazard occurred—illustrate the elasticity of the cooperative regional research and the responsiveness of the national system:

(1) the series of oat diseases in the midwest from 1941-1953, caused by *Helminthosporium, Septoria* and the new races of crown and stem rust;
(2) the serious outbreak of Race 15-B of stem rust of wheat which destroyed 60% and 75% of the durum wheat crop in 1953 and 1954 before it was brought under control;
(3) the new virulent form of bunt (stinking smut) in the Pacific Northwest which caused sharp increases in the carloads of wheat graded "smutty" in the early 1950s;
(4) the losses from black shank disease of tobacco in the Carolinas and Kentucky;
(5) the threats of bacterial wilt, the spotted alfalfa aphid and the stem nematode to alfalfa;
(6) the outbreaks of green bugs or aphids on wheat and small grains, and of corn root worms in the midwest;
(7) the threat of the Mexican fruit fly and the citrus black fly to the citrus industries of California and Texas; and
(8) the research leading to the control of the screw worm which has caused continuous heavy losses to livestock production in the southeastern U.S.

The foregoing are only a few of the more serious and "emergency" threats which received special intensive research attention during the 1940s and 1950s. They are above and beyond the continuing hazards which are systematically overcome by the production line precision of the national agricultural research system. To this list we could add many examples of research which has limited losses in the livestock and poultry industries, in stored products, in transport, and in many points between the field or the feed lot and the consumer. Such research has been most effective in providing for stability and dependability of production, a feature frequently overlooked because of the strong image of abundance of agricultural production in the U.S.

Research Support from the Agricultural Industries

A growing component—particularly during the past two decades—and a major factor in U.S. agricultural technology today, is the research conducted by private industries related to agriculture. In a study conducted by the USDA and the Association of State Universities and Land Grant Colleges [1966], it was found that of the total national support for agricultural research for fiscal year 1965 private industry spent $460 million, or 53.9%; the USDA $167 million, or 19.5%; and the state agricultural experiment stations $227 million, or 26.6%. It should be noted that of the latter, the state appropriations provided $118 million while the balance of $109 million was from federal grants and other sources.

The Farm Supply Industries

The industries that provide fertilizers, pesticides, improved seeds and farm equipment are concerned that their products are suited to the farmers' requirements, that they are used properly, and that they produce the desired results. Similarly, the industries serving agriculture in developing nations are today more positively interested in the farmer and his productivity than were the industries primarily concerned with purchasing the cotton, jute, sugar, rubber, bananas, or other cash crops destined for international markets.

The farmer who is moving into commercial agriculture with limited resources must allocate carefully his investments in seeds, fertilizers, pesticides and other inputs essential to increased productivity. The agricultural industries in developing nations, therefore, must be especially concerned about research to ensure efficiency as well as effectiveness of their production inputs purchased by farmers.

In order to promote proper use of their materials, industrial firms frequently conduct advisory services through their salesmen or dealers, and in many cases employ specialists in agronomy or farm management. Such an industrial extension service can supplement the activities of governments in transmitting information on new technology, but should not be expected to

replace the total government functions for extension and farm servicing which must transcend the task of technology transfer.

The farm supply industry has served agriculture well in Europe, North America and Japan. It is beginning to develop similar important supply and service functions in many of the developing nations and it is playing a particularly significant role in the intensified food grain production programs in Pakistan, India, the Philippines and other countries of Asia and the Far East.

The expanding role of private industry research in the United States and in the developing nations does not minimize the importance of a strong public-supported research structure. Such support will be required particularly for research in soil fertility and water management, in land use, in many aspects of livestock improvement, in the breeding of self-fertilized crops and for control of crop and livestock pests and diseases. Basic or background research and "non-commercial" technology such as the biological control of insects or weeds also should be a continuing responsibility of federal and state research organizations.

The Processing Industries

As agricultural development progresses, with greater productivity and diversification, the role of the processing industries becomes increasingly significant. The functions of storage, processing and marketing will require dependable supplies of high quality products. This calls for close association between the processors and farmers to ensure that production, harvesting, and transport practices and facilities are designed to maintain maximum quality throughout these operations.

In many of the agriculturally advanced nations the research of the food and other agricultural industries is the most significant factor in the improvement of uniform high quality in both processes and fresh produce. These industries, therefore, assume a substantial share of the research burden which would otherwise fall entirely upon the state and national governments.

In most developing countries, however, the private industry component is still absent or in its early stages of establishment. The more positive enlistment of the agricultural industry as an integral part of the national institutional system for develop-

ment and transmission of new technology would add a most important constructive force in increasing agricultural productivity.

Other Organizations or Associations

There are numerous organizations concerned with agriculture in the United States which have an effect on science and technology. The National Fertilizer Development Center of the Tennessee Valley Authority has made significant contributions to research in improvement and use of fertilizers in the United States [McCune, Hignett, and Douglas, 1966]. The TVA also is furnishing valuable leadership and guidance with respect to fertilizer requirements and supplies for many of the developing countries.

Various farm organizations, trade associations, or production and marketing associations have exerted a strong influence on research. The Crop Quality Council, the National Cotton Council, the National Association of Wheat Growers, and similar organizations concerned with soybeans, tobacco, citrus, and numerous other commodities have been effective in defining research problem areas and crystalizing budget support from federal and state sources. Although this type of relationship has been subject to the criticism that research may be excessively dominated by commercial agricultural interests, it has perpetuated a high degree of responsiveness and problem orientation in public-supported agricultural research.

Cooperative National Research Programs with International Dimensions

The U.S. agricultural research system has extended beyond national boundaries for many years in selected projects designed primarily to serve American agriculture. Many such projects, of course, have been mutually beneficial to the U.S. and the foreign nation participating.

We have numerous examples of international cooperation in crop and livestock improvement, particularly with respect to

pest and disease control. Research in soils has had strong ties to foreign scientists and research institutions for more than a century, and this collaboration has been enhanced in recent decades in soil classification, fertility and management.

For the purpose of this paper, two specific activities have been selected for review because of their particular relevance to international agricultural development at this time. The first is the program of plant introduction and the second is the national coordinated wheat improvement research program.

Plant Introduction

During these times of uncertainty about the degree of U.S. involvement in foreign aid or in international technical assistance programs it is especially pertinent to remind ourselves of the source of many of the basic inputs which have permitted the development of an abundant domestic agriculture in the United States.

Few of our economic crops are native to the United States. From the Western hemisphere, primarily from Mexico and Central America, we obtained varieties of cotton, beans, maize, chili peppers, avocado, vanilla and sisal. Peru, Ecuador, Colombia and Bolivia have been rich sources for basic germ plasm of the potato, kidney beans, lima beans, the papaya, tobacco and tomatoes. These countries also supplied varieties of squash and quinine. The cashew nut, the peanut, cassava and pineapples have been contributed by Brazil and Paraguay.

Northeast Africa has supplied barley, oats, rye, the castor bean, and sorghums. From the Near East countries we obtained the bread wheats, the almond, apricot, cabbage, carrot, and the cherry. This region of the world also provided grapes, summer squash and onions.

From India and South Asia came the club wheats and cotton, the apple, pear, cantaloupe, spinach, peas and sesame. And the Indo-Burma region furnished cowpeas, cucumbers, eggplant, hemp, mango, black pepper and rice. The East Asia countries contributed buckwheat, oranges, peaches, soybeans, sugarcane, grapefruit, banana, ginger, yams and the coconut.

These plants and others have been introduced and fitted to

American agriculture through a wide spectrum of basic, applied, and adaptive research. New introductions have furnished a continuing reservoir of germ plasm for use by our plant breeders in improving yield, disease and insect resistance, or other characteristics and qualities of our crops.

The collection, evaluation and maintenance of crop germ plasm was one of the earliest systematic efforts to improve U.S. agriculture, dating back to 1819 when the Department of the Treasury directed U.S. consuls to collect seeds, plants and information on crops and soils from the countries in which they were assigned. Twenty years later the Commissioner of Patents was authorized to collect foreign seeds and plants for distribution to farmers in the U.S., and in 1856 the Commissioner initiated a special activity for the propagation of sorghum. This was followed by a program for the distribution of cotton and tobacco seed in 1862, when the Department of Agriculture was established.

The introduction of plant materials was continued as a special function of the Department of Agriculture until 1901 when this activity was combined, together with other lines of research for crop improvement, into the Bureau of Plant Industry.

Interest in and support for foreign plant introduction has tended to rise or fall with the degree of concern expressed by individual scientists. The emphasis has changed also to reflect "emergency" requirements for exotic germ plasm as breeding stock for introducing resistance to new diseases or insect pests.

In 1947, the entire system of foreign plant introduction was reorganized and strengthened in recognition of the need to establish a more orderly and systematic program for the survey and collection of plant germ plasm from throughout the world, for the evaluation and cataloguing of data to permit prompt identification of genetic qualities, and for maintenance of stocks or seeds to ensure prompt availability to federal, state, and private plant breeders.

A continuing budget was set up for support of foreign travel and field explorations. Facilities were improved at the primary introduction and quarantine station at Glenn Dale, Maryland, and at selected other centers where initial introductions are grown. Regional stations were established cooperatively with

the state agricultural experiment stations at Ames, Iowa; Experiment, Georgia; Geneva, New York; and Pullman, Washington, to handle the propagation, testing, maintenance and distribution of the introduced germ plasm stocks of crops of special importance in each region. An interregional station for the study of genetics, breeding and pathology of the potato was set up at Sturgeon Bay, Wisconsin.

In addition to the new plant introduction stations designed to serve more effectively the plant breeders in the various types of farming regions, the National Seed Storage Laboratory was established in 1956 on the campus of Colorado State University where small samples of all important crop germ plasm stocks are maintained under conditions of low temperature and humidity.

Many of the U.S. crop germ plasm collections have been utilized in international programs through the regular interchange of materials with other countries. Such use has been accelerated in recent years through special activities such as the adaptive research of the agricultural sciences program of the Rockefeller Foundation. The U.S. wheat germ plasm collection has been an especially important resource for the international wheat improvement program headquartered in Mexico. The rice collection furnished the base of the very excellent and now much more extensive germ plasm resource at the International Rice Research Institute. And the sorghums and millets collections—together with participating U.S. plant explorers—have contributed to the broad genetic base of these crops maintained in the U.S. and in India.

The special project supported by the National Academy of Sciences-National Research Council for collection of races of maize in Latin America, initiated in the 1940s, resulted in the collection of more than 12,000 lines which are maintained in the germ plasm banks in Mexico, Colombia and Brazil [Clark, 1956]. These collections are being classified and "composites" have been made of some of the outstanding breeding stocks into about 200 special races.

Although the foregoing collections of the major food grains have been "internationalized," with germ plasm banks maintained in the Philippines, India and Latin America, only lim-

ited progress has been made in developing an effective international organization for the collection, utilization and maintenance of plant and animal germ plasm. The initiatives taken by the Food and Agriculture Organization more than 20 years ago have received only limited support, not only from the agriculturally advanced nations and from the developing countries but from FAO itself [Harrington, 1958b]. Increasing numbers of agriculturists concerned with germ plasm resources are becoming aware of the need to protect the genetic diversity through pools developed in the centers of origin of the particular plant or crop [FAO, 1967]. This would be over and above the collection and utilization of new genetic stocks to meet specific current problems of disease or insect resistance and crop quality.

Nations with advanced, science-based agriculture must constantly shore up the organization and operation of the important components of their total national systems of agricultural research. *In the U.S. we have given more continuous attention to the strengthening of our agricultural research capability in the past two decades than we have given to the building or enhancing of such capabilities in developing nations in our cooperative, technical assistance programs.*

The National Wheat Improvement Research Program

The cooperative federal-state coordinated research on wheat improvement is an excellent example of a national program with strong regional and local orientation within the United States which has come to have significant international dimensions. The organization and operation of this program reflects the pattern utilized in the cooperative research programs for food crop improvement supported by the Rockefeller Foundation and in a number of the research projects supported by the Agency for International Development.

The roles of the USDA and the participating states in the national program are similar to those of the Rockefeller Foundation staff and the collaborating countries, or of the central leadership of the AID-supported projects and the participating countries in international efforts. The national wheat research program also furnishes a pattern for tackling a variety of prob-

lem areas in national agricultural research systems where new crops are to be established or old crops are to be made more productive.

Wheat is not an indigenous crop in the U.S., and, as stated by Reitz [1962, 108]:

> It came to us from halfway around the world as food for colonists in the New World or in the luggage of immigrants, who knew its worth. The introduction of wheat from many lands provided an array of varieties and kinds for colonists to try. Many kinds failed because they were not suited to the soil and climate in the places they were planted, and they were replaced by seed from varieties that did succeed. Wheat became established by this process along the Atlantic coast before 1800. The process was repeated as settlers moved westward. Wheat was beginning to look like a native in America by 1859. Now it is grown regularly in 44 states.

The early trial and error process for identifying types of wheat adapted to specific growing conditions has progressed to a systematic procedure for the continued introduction of new germ plasm from abroad, and the biological engineering of plant breeders, physiologists, pathologists, soil scientists and other agricultural researchers to increase productivity of the crop under a wide range of environments. The total national effort is coordinated and serviced through the USDA which participates in the research; assists with the planning, conduct, analysis, and reporting of uniform nursery trials; supports the staff and facilities for milling and baking quality tests; and furnishes a constant flow of new germ plasm from the worldwide collection of wheats which now numbers more than 18,000 lines.

Since there are market demands or consumer requirements for the various classes of wheat which tend to be specifically adapted to different growing environments of the country, the national research program has been developed on a regional pattern. Beginning in the late 1920s a coordinated program was established for the improvement of the hard red spring wheats, involving the states of the northern great plains and north central region. Subsequently, cooperative programs were established for hard red winter wheat, including the states from

Texas through the Dakotas and Montana; for the soft red winter wheats in the eastern U.S.; for the white wheats in the Pacific Northwest and California; and for the durum wheats in the Dakotas and Montana. The coordinating leadership, furnished initially by USDA personnel located in Washington, D.C., has been supplied in more recent years by USDA scientists actively participating in the research and located at one of the experiment stations within the region, i.e., in Maryland, North Dakota, Nebraska and Montana.

Effective interdisciplinary research attention is furnished by the plant breeders, pathologists, biochemists, soil scientists, entomologists and other specialists from either the cooperating experiment stations or from the USDA, who are usually located at a state agricultural experiment station. The assignment of federal scientists to cooperating state experiment stations permits the formation of well balanced research teams within a state, as well as throughout the specific wheat growing region.

Of the wide range of services provided by the national coordinating leadership, the collection and distribution to plant breeders of new germ plasm has been of particular value. The use of Norin 10 wheat in breeding the short-strawed, high-yielding, fertilizer-responsive varieties is of special interest because of the international benefits which have accrued from this germ plasm. Norin 10 and other varieties of this type were brought to the United States from Japan in 1946 by Dr. S. C. Salmon who at that time was leader of the USDA wheat investigation program and was serving as agricultural adviser to the occupation army in Japan [Reitz and Salmon, 1968].

Dr. O. A. Vogel, the USDA plant breeder located at the Washington Agricultural Experiment Station, Pullman, Washington, was the first wheat breeder in North America to use the semi-dwarfs extensively. Progeny from his crosses of Norin 10 x Brevor and Norin 10 x Baart have been used widely in the United States and also furnished the base for development of the semi-dwarf "Mexican wheats" by Dr. N. E. Borlaug of the Rockefeller Foundation and cooperating Mexican plant breeders. Derivatives of Vogel's hybrids crossed with Mexican varieties, and of similar crosses of Mexican varieties with Norin 33 x Indiana wheats, brought to Mexico from Purdue University in

1957 by Dr. Ignacio Narvaez, were distributed to farmers in Mexico in 1962.

The performance of the Mexican semi-dwarfs, which are relatively insensitive to length of day and which have been grown widely in West and South Asia in recent years, is well known. It has been estimated that these wheats now cover about 15-20% of the total wheat acreage in India and Pakistan and that wheat production in West and South Asia may be increased by about 20% in 1968-69 through their use [Dalrymple, 1969].

Less well-publicized is the performance and widespread impact of the Norin germ plasm in U.S. wheat production. A number of varieties have been developed from crosses of local wheats in the various wheat-growing regions with the Norin 10 x Brevor stocks produced by Dr. Vogel. The varieties *Gaines* and *Nugaines,* developed in the cooperative program of the USDA and the Washington, Oregon and Idaho agricultural experiment stations, were released in 1961 and 1965, respectively. These varieties covered about 2.5 million acres of the Pacific Northwest wheat acreage in 1968. A number of farmers have obtained yields of more than 100 bushels per acre and a world-record yield of 209 bushels was produced by a farmer in Washington with the variety Gaines in 1965 [Reitz, 1969].

The variety *Maricopa,* a semi-dwarf, white spring wheat suited for fall seeding in Arizona, was released by the Arizona Experiment Station in 1961. The soft red winter wheat variety *Blueboy* released by the North Carolina Experiment Station in 1966 produced more than 100 bushels per acre in North Carolina in 1967, the first variety to achieve this yield level on a farm scale east of the continental divide. The variety *Yorkstar,* a short-strawed, white-grained winter type, was released by the Cornell University Agricultural Experiment Station in 1966. *Timwin,* a semi-dwarf, soft red winter wheat, was released by the Wisconsin Agricultural Experiment Station in 1967 [Reitz and Salmon, 1968].

A second major contribution of the nationwide wheat research program has been its role in restricting disastrous outbreaks of diseases or insect pests. The plant pathologists and entomologists "dispersed" at state and federal research stations

are able to detect and immediately begin to combat a new form of disease or insect pest found in any section of the major wheat growing regions.

An example is the experience with the virulent Race 15-B of stem rust which was first found near the alternate host barberry bushes in the northern U.S. by plant pathologists in 1938. Work was undertaken promptly to identify sources of genetic resistance, including wheat varieties introduced from Australia, Kenya, Egypt, and elsewhere. The research was handicapped by reduced budgets and personnel during World War II, but by the time this race of stem rust was first discovered in farmers' fields, in 1950, the plant breeders and pathologists were well along in the breeding of adapted, commercially-suitable varieties with a high degree of resistance to it. Cooperation of plant breeders and pathologists from Texas through the Dakotas and Minnesota—as well as from the Rockefeller Foundation-supported wheat research project in Mexico and from the Dominion Rust Laboratory at Winnepeg, Canada—not only shortened the cycle of losses from rust Race 15-B but has effectively headed off subsequent serious outbreaks of wheat diseases.

The research approach to the control of Race 15-B typifies the problem-orientation of modern agricultural science. The awareness that different forms of the pathogen could arise, with varying levels of virulence or potential destructiveness, caused the research staff to move immediately in meeting a potential hazard which in this case became a reality. The losses of 60 and 75 percent, respectively, of the potential durum wheat crop in 1953 and 1954 were extremely serious but of short duration because of the fortunate research lead time.

Agricultural scientists in the U.S. who are concerned with such applied and directed research are usually well aware of deficiencies in the materials or methods currently used on farms. They are alert also to potentials for application of new basic knowledge and so supply a high degree of "innovation" as well as "responsiveness" in research.

International cooperation has been a basic part of the federal-state wheat improvement program for several decades. Special nurseries of selected varieties or breeding lines were sent to

Canadian experiment stations to determine winter hardiness and also disease reaction, beginning in the 1920s. Following the appearance of Race 15-B of stem rust, international cereal disease trials became an important part of the coordinated federal-state research program, with uniform nurseries grown by cooperators in Latin America, Europe and the Near and Middle East countries. Approximately 150 scientists have been cooperating in this program in recent years, at 85 locations in 40 countries.

Wheat research is probably more highly organized on a national and regional basis than any other U.S. crop improvement program. However, the basic pattern of strong federal government participation and support for problems of national and regional concern, with active participation by the state experiment stations in such projects, together with state-supported attention to the specific environments within their boundaries, is characteristic of many other cooperative research activities serving U.S. agriculture.

An Assessment of the U.S. Institutionalized Agricultural Science System

Sir Eric Ashby [1966, 3], the British educator, has stated:

> An institution is the embodiment of an ideal. In order to survive, an institution must fulfil two conditions: it must be sufficiently stable to sustain the ideal which gave it birth and sufficiently responsive to remain relevant to the society which supports it.

Organizational and Budgetary Stability

The national system of agricultural research in the United States has the stability provided by the Acts of Congress in 1862 establishing the U.S. Department of Agriculture and providing the grant of land in each state to support the development of "at least one college where the leading object shall be . . . to teach such branches of learning as are related to agriculture and the mechanic arts . . ." [USDA, 1962, 218]. Subsequent legislation

and budgetary support at the federal level, and from the state legislatures, have contributed to the growth and stability of the total national program of agricultural research.

The U.S. Department of Agriculture research has gone through numerous reorganizations and shifts in emphasis during the past century, including the change from the strongly discipline-oriented organizational pattern of the early years to a greater degree of interdisciplinary and problem-oriented research, particularly in the 1920s and 1930s. There have been recurrent shifts toward centralization of research at the federally-supported laboratories or toward decentralization of support with greater collaboration with state agricultural experiment stations. These changes have not caused serious instabilities in the national system but have usually resulted in strengthening it.

The foregoing presentation of the development, operations, and cooperative relationships between the state agricultural experiment stations and USDA research might leave the impression that this total national institutionalized system is a continuously harmonious and smoothly functioning program. This, of course, is not the case. The state experiment stations have full autonomy, and are privileged to operate separately from each other as well as from the federal government.

The USDA, in like manner, is authorized to operate with a high degree of autonomy. Although the major interest is in problems of regional or national concern, the USDA responds also to requests for research on highly localized problems. This is reflected in the sizeable number of federal field stations and laboratories which have persisted throughout the country over the years.

Although a legal-financial linkage is provided through the federal grant funds, the collaborative efforts are largely voluntary. Federal-state cooperation tends to be especially close during periods of stress or when there are special demands for research inputs. The relationship tends to become less close and harmonious when the pressure for agricultural production is relaxed—a situation which has prevailed during most of the period since the end of World War II.

A number of factors have contributed to the looser linkage between federal and state agricultural research in the past 20 years. The provision of special funds under the Research and Marketing Act of 1946 for regional research to be conducted by the states themselves tended to reduce USDA involvement in some such regional projects [USDA, 1962, 225]. In addition, the availability of research funds to individual scientists from such federal organizations as the National Science Foundation, the National Institutes of Health, the National Aeronautics and Space Administration, etc., has drawn a number of the more able agricultural scientists away from applied or problem-oriented investigations into more narrowly defined fundamental or basic research. This has caused an isolation, or at least an independence, of such scientists within the state agricultural experiment station structure as well as in cooperative federal-state activities.

The net effect of the various forces that have modified patterns of agricultural research in the United States during the past 20 years has been to blur or mask the national institutional structure and to obscure coordinated programs such as those in plant introduction and in national wheat improvement. *It is important, therefore, for those who wish to study the organization and functioning of the U.S. agricultural research system to concentrate attention on specific activities to see how they are structured and integrated.* In this regard, one of the more perceptive analyses of U.S. agricultural research by foreign agricultural specialists was that of Messrs. P. P. I. Vaidyanathan and K. C. Naik on a short visit from India in 1958. Their report *Agricultural Institutions in the United States of America* furnishes not only an excellent summary of the U.S. structure but also a comparison with the pattern of Indian agricultural research institutions.

Flexibility and Responsiveness

We have numerous examples of the responsiveness of the national system in meeting emergency situations, particularly in protecting U.S. agriculture. We have ample evidence also of the effective marshalling of the federal-state research resources

to meet the critical needs of World War I, World War II, and the Korean emergencies. And special legislation has provided for broadening the research into economic and social science areas, into utilization and marketing problem fields, and for deepening the background and basic research.

The limiting factors confronting farmers do not conform to political boundaries. They transcend not only state lines but also the regional areas embraced by the groupings of the state experiment stations, by the former organizational pattern of the Soil Conservation Service, or similar associations. The overlay of federal support for "regional research" on problems with diverse boundaries provides a high degree of elasticity in the national research program.

Applicability to Developing Nations

In considering applicability of the U.S. agricultural research system to developing nations, we would not expect either its specific organizational pattern or its evolutionary development to have direct relevance. But for those countries interested in building their institutional capabilities for agricultural science and technology a number of points might be stressed:

(1) Specific attention should be concentrated on the planning and evolution of capabilities for problem-oriented, interdisciplinary research. This cannot be generated spontaneously from institutions established to devote primary attention to teaching, extension, or other agricultural development activities.

(2) The U.S. agricultural research pattern is not subject to limitations of scale and has applicability in small countries as well as in larger nations. The principal difference will be the numbers of research stations or laboratories, the number and complexity of specific projects, and the number of scientists required.

(3) Assessment and potential applicability of the U.S. pattern should consider: (a) a strong nationwide system including such regional and local research centers as may be required for diversity of the agricultural environments; (b) the association of teaching and training programs at selected research centers,

with the nature of the research and education linkage designed to furnish the training necessary for specific agricultural specialists; and (c) a close linkage between the research centers and extension and other activities responsible for helping farmers to use new technology.

These factors will be discussed more fully in considering the strengthening of national agricultural research systems in developing nations.

Chapter III

AGRICULTURAL RESEARCH ORGANIZATIONS IN THE DEVELOPING NATIONS

It is difficult to generalize about agricultural research capabilities of the developing nations. A number of institutional changes have been brought about since the early 1940s when the Inter-American Institute for Agricultural Sciences was established in Costa Rica, and when the Rockefeller Foundation initiated its cooperative agricultural program in Mexico. But looking at the world of newly-independent nations and Latin America as a whole there has been disappointingly little improvement in indigenous capabilities for agricultural research over the past 25 years. In fact, in a number of countries which have achieved independence since World War II the agricultural research capability has deteriorated as expatriate scientists have departed and their replacements have been relatively inexperienced and/or inadequately trained.

Some Organizational Patterns

In the former British colonies there is a rather consistent pattern of central research institutes, concentrating primarily on fundamental or basic studies related to specific commodities—usually export crops. Only limited attention has been given to the broad-scale adaptive research essential for agricultural diversification and modernization. This pattern prevailed in pre-independent India and Pakistan with their central research institutes for jute, cotton, sugarcane and other crops, and in Africa where research institutes were set up to serve the

broader regional areas of West Africa concerned with rubber, cocoa and oil palm. The establishment of the Rubber Research Institute of Malaya in 1925 also reflects the special interest in technical backstopping for commercial crops, with limited research attention to the balance of the agriculture in the country.

In India and Pakistan agriculture is considered a state responsibility, although research is accepted as a joint or concurrent task for state and central government attention. Since tax resources at the state level are limited, it is difficult to obtain much support through the state ministries of agriculture for research. As a result, applied or adaptive research to resolve problems of cultivators, a task left primarily to the states, has been largely neglected.

Research is not a major activity of the colleges or schools of agriculture in many developing countries. These are primarily teaching institutions with curricula and procedures strongly guided by the universities to which they are affiliated.

In India and Pakistan there are Councils of Agricultural Research which provide financial support to selected projects. In the absence of a strong national research infrastructure, however, the relatively modest and usually short-term allocations of funds to narrowly defined projects within special disciplines furnish limited practical or cumulative benefit. India has taken positive steps in the past decade to develop All-India research projects and to strengthen its national organization for adaptive and applied research, with the funds of the Indian Council of Agricultural Research channeled substantially to such coordinated All-India projects.

In general, agricultural research in developing nations is more personalized than organized, and depends largely upon the initiative, vigor and level of training of individual research workers. The sugarcanes from the research station at Coimbatore, India, and the "noble canes" from Java have been important resources for developing the sugarcane industry around the world, and individual British, Dutch and Belgian scientists have made outstanding contributions to the understanding of biology and agriculture in the tropics. These contributions have diminished since World War II, however, in part because of the

loss of expatriate scientists following independence, in part because of the efforts to borrow technology through "extension" programs, and also because of the strong emphasis by many of the developing nations on industrial development.

The priority given to highly action-oriented technical assistance programs by many donor organizations has perpetuated the depressed level of agricultural research in many of the developing countries. As stated by a leading Indian agricultural scientist a few years ago, the slow pace of modernization of agriculture is not because of a lack of willingness to accept innovations on the part of the cultivator. The major limitation is the lack of support by political and administrative leaders for the research to produce innovations.

Research Personnel

Dr. Frederick Seitz, past President of the U.S. National Academy of Sciences, in expressing concern recently about the possibility of smaller numbers of U.S. students going into the sciences in future years, stated [Seitz, 1968a, 29], "There is no substitute for having quantities of bright people—it's been the basis of our strength for the last 25 years."

We develop some appreciation of the significance of this intellectual strength in U.S. agricultural science and technology as we thumb through the USDA directory of *Professional Workers in State Agricultural Experiment Stations and Other Cooperating State Institutions* [USDA, 1965] and note the number of personnel with M.S. and Ph.D. degrees. There are from 50 to 100 or more Ph.D. holders listed on each of the 188 pages of the directory for 1965-66. The state experiment station-USDA research staff resource totalled 10,330 scientist man-years in 1965.

The lack of scientific manpower is the major limiting factor in the upgrading of agriculture in most developing nations today. The Minnesota Agricultural Experiment Station has more Ph.D-trained personnel at its Northwest Branch Experiment Station at Crookston, and at its Southern Branch Experiment Sta-

tion at Waseca, than does the entire Research Branch of the Division of Agriculture of the Government of Malaysia.

The large number of research scientists in the United States, and the concentration of multidisciplinary teams at major research centers, together with the dispersal of well-trained personnel to local experiment stations has an important impact on the extension of technology to farmers. The extension worker in northwestern Minnesota or in the southern part of that state has a proved resource—from the nearby experimental farm—to offer to his farmers. This is in sharp contrast with the task of extension workers in Asia in recent years who are confronted with the responsibility for recommending the improved rice or wheat production technology developed in the Philippines and Mexico but which has been subjected to little adaptive research and only limited testing in local research stations.

The Level and Quality of Training

In most developing nations there are few agriculturists trained beyond the B.S. degree level, although in the countries following the British university pattern there are increasing numbers with the B.S. Honors degree (essentially equivalent to the M.S. degree) in the scientific disciplines related to agriculture. There is, however, still a rather common view that because of the relatively low state of traditional agriculture, substantial modernization or upgrading can be achieved by individuals trained only through the B.S. degree. This, unfortunately, is a misconception to which too many U.S. agriculturists contribute by suggesting that "technical assistance tasks can be handled by a good county agent or extension specialist." These words have a familiar ring as we recall the controversy with respect to "solid research" versus "expedient demonstrations" in the evolution of the U.S. experiment stations.

Actually, the tasks of crop breeding and improvement, soil and water management, disease and pest control, livestock improvement and management, and animal health problems, etc., are as complex in tropical agricultural regions as they are anywhere in the U.S., and usually more so. The economic and social problems also are equally difficult and the same level of research competence is required to meet them.

We would not expect students trained through the B.S. degree in general agriculture to be effective researchers in the U.S. The training and experience in conceptualizing a problem and organizing an investigation to resolve or learn about it is acquired largely in the M.S. and Ph.D. training programs. And until the level of professional capability of agriculturists in the developing countries is raised, not only for research but also for extension and advisory services, much of the technological input will continue to be second-hand and second-class.

Some of the developing countries have substantial numbers of individuals who have received advanced training in the sciences related to agriculture at universities in the U.S., the U.K. or other agriculturally advanced nations. Their contribution to practical agricultural development in their own country will be limited, however, if their academic experience is concentrated on theoretical issues, if on return to their home country they have inadequate leadership to help them focus on significant local problems, and if they lack the organizational base in their home country to supply budgetary support and program stability.

Research Aptitude and Dedication

Although the level of academic training, through the M.S. or Ph.D. degree, provides a measure of *intellectual* competence, in-service or working experience in experimental methodology is equally important. This competence to plan and carry out research varies widely in the developing nations and the provision of training in experimental projects, particularly in actually handling field and laboratory research, has become an increasing problem as agricultural scientists in the U.S. have turned toward more specialized research, much of which requires highly sophisticated equipment.

A prominent feature of the Rockefeller Foundation agricultural programs from their beginning has been the strong emphasis on in-service or working experience in conducting research. Over 700 young Mexican colleagues have been trained in this apprentice relationship and similar in-service training has been a part of the cooperative Foundation programs in

Colombia, Chile and India. These national programs and the international research institutes for rice in the Philippines and for corn and wheat in Mexico are especially effective in providing this type of training.

A most important, though somewhat intangible, characteristic of an effective agricultural scientist is his vigor, enthusiasm and dedication to the task of problem-solving. Without these traits a well trained and highly intelligent research worker tends to accomplish very little. Although these characteristics are in part inherent, they may be enhanced or diminished also by organizational support and working environments. There is a too common tendency to criticize research personnel in developing countries for a lack of willingness to get their hands dirty or to work in experimental plots. It is not usually appreciated that the absence of a solid organizational or institutional base, with attendant career uncertainties, may be important contributory factors.

Career Specialization

The lack of a strong and stabilized organizational structure for research, along either commodity or problem lines, fosters the frequent transfer of research workers from one project to another. It is not uncommon for a plant scientist to have worked on three to five different crops over a ten-year period, with the moves motivated primarily by modest salary advances in the new field. Such transient personnel contribute little in advancing technology during their careers.

Another limiting factor in many developing nations is the tendency to place responsibility for a broad scope of research in the hands of a single individual. In some countries it is common practice to designate one economic botanist at a research institute as the leader for crop breeding and improvement research for a number of major economic crops such as wheat, cotton, sorghums, millets, oil seeds, etc. Even though he may have a sizeable number of lesser trained subordinates, no one person, no matter how competent, can furnish incisive and progressive leadership to this scope of research.

Strengthening Training Programs

A solid agricultural research base—with the level of scientific capability required to make it productive and the level of competence of farm advisers or extension workers necessary for effective transfer of innovations into practice—will require substantial upgrading in the agricultural education structure in the developing nations. In most cases the targets for numbers to be trained to the M.S. or Ph.D. degree levels are still far too low. It is questionable also whether the strong emphasis on vocational training, through the level equivalent to the U.S. high school, will produce agricultural advisers or extension workers with the capability to understand the significance of *properly combining* the packages of practices or inputs of modern agricultural technology.

Substantial progress has been made in a number of countries where scholarships and fellowships of various agencies, both domestic and foreign, have produced a strong corps of well-trained scientists. Also, under the AID contracts with U.S. land grant universities the participant or training component has been utilized by the universities to train many students from the cooperating countries to the M.S. and Ph.D. levels. As a result, there is now a growing nucleus of well-trained agriculturists in countries where the U.S. universities have been collaborating for a decade or more. In many countries this represents the best agricultural specialist resource available.

If developing nations are to move into modern science-based agriculture, however, they cannot depend upon external aid for advanced training. They must invest their own funds—and invest heavily—in building this national research capability. Experience over the years in training and education of agriculturists from developing countries suggests that an effective pattern might include: (1) in-service training in experimental methods for field and laboratory research through apprenticeship in well-designed, problem-oriented research projects in the home country, another country in the region, or at one of the specialized regional or international research institutes; (2) following the in-service experience, proceed with training

to the M.S. degree level at an institution in the home country, within the region, or at a college of agriculture associated with one of the regional or international research institutes; (3) for those especially suited for research leadership, continue the training through the Ph.D. level at institutions—at home or abroad—selected on the basis of their suitability for the specialized needs and interests of the individual. At this stage the primary concern would be for education in depth in a specialized area, combined with reasonable breadth of exposure to related scientific disciplines.

General Program Deficiencies

The lack of nationally structured research organizations together with inadequate numbers of well-trained research specialists have been the more critical limitations in generating agricultural technology in the developing countries. Beyond these restraints, however, there are additional program or operational problems to overcome.

The concentration of attention on export crops has resulted in inadequate concern for improved production of food grains and feed crops, or to the design of diversified cropping systems to achieve maximum productivity of land and water resources. An especially neglected area is research on soils and water management, including the conservation and use of rainfall. This problem has been reviewed critically by the Asian Development Bank team [1969]. Few countries have given serious attention to livestock improvement, and the research on economic and social problems in agriculture is extremely deficient.

The emphasis of research institutes on fundamental studies has tended in many instances to limit attention to practical solutions for immediate problems or hazards which inhibit productivity. Agricultural research organizations are frequently organized on a discipline basis, i.e., divisions of botany, chemistry, mycology, entomology, etc., with a tight compartmentalization which inhibits joint attention to complex agricultural problems. Also, as mentioned earlier, a staffing pattern which places responsibility for a broad program of research in the

hands of a single economic botanist, soil scientist, mycologist or veterinarian restricts the scope of intellectual thrust in planning and conducting research.

Domination by non-technical administrative personnel in decisions on the development of budgets, the release of funds, the recruitment and selection of professional staff, the approval of travel, the purchase of equipment and supplies, and similar functions is another serious handicap. This varies in different countries, but in very few instances do we have acceptance of the U.S. pattern where the director of a research institute or station is a trained scientist and the administrative functions, which should be handled by skilled management personnel subordinate to the director, are recognized as services to be performed in such a manner as to expedite the research programs.

The inadequacy of research facilities—laboratories, field stations, and scientific instruments—is a general handicap, and frequently one of the most difficult to assess. Perhaps the most common deficiency in agronomic research is the lack of precision in field experimentation because of plot lands poorly suited to exact and reproducible trials, with inadequate control of irrigation or moisture management and ineffective weed, disease or pest control.

The limitation in research capability in developing countries not only restricts the amount and quality of research by the domestic staff and organizations but also restricts, sometimes seriously, opportunities to utilize external scientific and technical assistance. Foreign experts and support cannot be helpful unless there is at least a minimum standard of local professional competence and research facilities for effective joint adaptive research endeavors.

Chapter IV

TECHNOLOGY IN U.S. TECHNICAL ASSISTANCE PROGRAMS

The sustained flow of new technological inputs into U.S. agriculture in the form of improved crop varieties; more effective crop disease and pest control measures; better soil fertility and water management practices; improved machines; improved livestock with better nutrition, management and disease control; and other off-the-farm contributions has generated continuously higher levels of productivity in all crop and livestock producing regions of the country. The prompt and continuous application of innovations from the combined efforts of the USDA, state agricultural experiment stations, and agricultural industries minimizes hazards to production, ranging from problems of broad national concern to those of small groups of farmers within localized farming communities.

Despite the strong dependence of U.S. agriculture on this steady generation of new technology, the U.S. technical assistance programs for nearly two decades have neither developed nor utilized new agricultural technology in the cooperating countries with any real degree of effectiveness. The potential for improved technology in the developing nations is fully evident from the low levels of productivity, as measured in crop yields per acre, and has been amply demonstrated in the boosting of productivity by the new "packages of practices" for wheat and rice production in the past three years in India, Pakistan and other countries of Asia.

Many factors contribute to the neglect of research to develop new technology inputs in U.S. technical assistance programs.

Some, but not all, are the fault of the Agency for International Development and its predecessor agencies. The selection of priorities has been strongly influenced by short-term authorizations and appropriations by the Congress. Shifts in program emphasis—often precipitous—together with frequent reorganizations and transfers of personnel, are faults partly of the Agency and partly of changes in political administrations. But the community of agricultural scientists in the U.S., from the USDA research agencies and the state agricultural experiment stations, has not made the positive contribution of which it is capable in either participating in or guiding the cooperative international development programs. For various reasons they have tended to stand back and aside in the U.S. foreign aid efforts.

We have had a variety of experiences in the transfer of agricultural technology between countries and also in the building of indigenous institutional capabilities for research which should be assessed to identify more effective approaches in strengthening the technological base of international agricultural development.

Early U.S. Government Cooperation in Technical Assistance

Cooperation in the Americas

Some of the earliest bilateral cooperative programs in agriculture were those conducted by the governments of Mexico and the United States for control of plant and animal diseases, including the cotton pink boll worm, the Mexican fruit fly, the citrus black fly, and aftosa or foot and mouth disease in cattle [Mosher, 1957]. These were primarily control programs designed to prevent the spread of the hazards to the United States, but research components were included in the plant disease and insect control programs, with cooperating U.S. scientists stationed in Mexico.

The Rubber Development Program, initiated in the early

1940s to improve sources for natural rubber in the Western hemisphere, was administered by the Bureau of Plant Industry of the USDA, although the funding was furnished through the Department of State. This program involved cooperative investigations with twelve Latin American nations. In 1954, in a move to consolidate all overseas activities, the rubber investigations program was transferred from the USDA to the Technical Cooperation Administration. This action was taken in spite of the fact that the program was designed primarily to serve the interests of the U.S. rather than the agricultural and economic development of the cooperating country. After its transfer, the regionally coordinated program was fractured into "country oriented" components and rapidly disintegrated.

The "complementary crops program" established under the USDA Office of Foreign Agricultural Relations was concerned primarily with research to stimulate production in Latin America of selected crops not grown in quantity in the United States. The agreements with cooperating governments called for a continuing program extending for ten years, from 1942 to 1952.

The Institute of Inter-American Affairs, organized in 1943 under the Office of the Coordinator of Inter-American Affairs, established programs initially in nine countries to accelerate agricultural production significant in the war effort.

It has been pointed out that the programs of the OFAR were handicapped because of the restriction to complementary crops such as coffee, bananas, etc., which would not be competitive with U.S. agriculture. Similarly, the pressure for immediate results from the programs of the IIAA resulted in heavy emphasis on extension or operational programs designed to achieve quick increases in production.

There were certain bureaucratic conflicts between the several U.S. agencies involved in similar programs in Latin America, including the Bureau of Plant Industry and the Office of Foreign Agricultural Relations of the USDA, and the Institute of Inter-American Affairs. This problem was resolved in part by the transfer of the OFAR activities to the IIAA in 1952. The Rubber Development Program of the Bureau of Plant Industry

was sufficiently distinct to minimize particular conflicts, and the absorption and eventual dissolution of this program by the Technical Cooperation Administration in 1954 erased such minor jurisdictional difficulties as did exist.

Agriculture in the Marshall Plan

The new technology input for agriculture in the Marshall Plan period, from 1948 to 1951, was relatively modest. The transfer to Europe of the materials and techniques for production of hybrid corn was perhaps the most significant contribution during this period. The program of introduction of U.S. corn hybrids into Europe under the early auspices of the United Nations Rural Rehabilitation Administration (UNRRA) in Italy in 1946, was formalized and extended in the summer of 1947 when the first conference of European corn breeders was held in Bergamo, Italy [Nichols, 1954]. In 1948, Dr M. T. Jenkins of the USDA furnished the coordinating leadership for a project supported by the FAO for the first extensive cooperative trials with U.S. corn hybrids in Europe. A number of U.S. corn breeders followed Dr. Jenkins in providing technical leadership. This was an adaptive research program guided by competent scientists, and since the temperate zone environment of the European countries is similar to the corn-growing areas of the U.S., a number of the U.S. inbreds and hybrids were found to be well suited.

Although this direct introduction of U.S. materials and practices provided a running start for European corn growers in benefiting from new U.S. agricultural technology, it has been a mixed blessing since it created the impression among many subsequent U.S. technical assistance specialists that U.S. "know-how," including crop varieties and cultural practices, could be used directly to modernize agriculture and increase productivity throughout the world. A most significant oversight in these subsequent efforts was the failure to involve trained and experienced scientists to guide the adaptive research and testing, a need especially critical in fitting modern technology to the tropical and subtropical environments of the developing nations of Asia, Africa and Latin America.

Agricultural Technology in the Point IV Program—After 1951

The major thrust of "Point IV" in President Truman's inaugural statement of January 1949 was on the sharing of technical advances of the U.S. with less advantaged countries of the world.

It is of interest to note that when the initial steps were taken by the Department of State later in the year 1949 to conduct preliminary planning for the prospective Point IV Program, the research-oriented work of the OFAR was regarded as having special significance. Dr. Ross E. Moore, Chief of the Technical Collaboration Branch of the OFAR, was selected to head a team of agricultural specialists (including the writer, who represented the USDA's Agricultural Research Administration, and Paul V. Kepner of the USDA's Extension Service) to review needs and opportunities in implementation of the program [Drosdoff, 1966].

During the three months beginning January 27, 1950, the team met with representatives of the governments of Egypt, Syria, Lebanon, Iraq, Iran, Pakistan, India, Afghanistan, Ceylon, Thailand and the Philippines to identify specific problems in agriculture and areas of potential collaboration.

It was the consensus of the review team that the cooperative agricultural development should involve (1) the strengthening of extension services, (2) the prompt application of available indigenous and introduced technology through cooperative research and technical assistance, and (3) the strengthening of the indigenous research capability. As a result of the trip, steps were taken early in May 1950, prior to the passage of the Point IV legislation, for several projects "of a Point IV nature" to be carried out in Asia under Public Law 402 authorization. These included cooperation with Iran for development of agricultural extension and research, with Ceylon in an agricultural extension program to increase rice production, and with Pakistan to improve agricultural extension work. In addition, specialists were sent to the Philippines to cooperate in agricultural extension and in plant disease research and to Thailand to assist with research on rice breeding and soils improvement.

Emphasis on Extension and Community Development

In the subsequent implementation of the Point IV program, major emphasis was placed on extension projects designed primarily to transfer U.S. materials and practices directly. This "extension bias" met with only limited success because of the paucity of applicable indigenous technology and the general unsuitability of U.S. temperate zone materials and practices to tropical agricultural conditions. A few examples of successful introduction of new crop varieties or practices can be cited, but the sparse and transient results from this approach fell far below the requirements to achieve a truly growing and progressive agriculture in the cooperating developing nations.

The strong emphasis on extension in the initial formulation of the Point IV program resulted in the recruitment of many agricultural specialists whose training and experience had been largely in extension and operational activities. This pattern of staffing and program orientation has tended to persist in dominating "technical assistance" and there still is only a limited number of agricultural scientists, with experience in the organization and conduct of research, in the U.S. foreign aid program.

The widespread enthusiasm for "community development" during the early 1950s resulted in the application of substantial resources to these multipurpose programs which gave simultaneous—but usually somewhat superficial—attention to health and sanitation, road improvement, etc. These activities were, of course, useful in bringing about a greater cohesiveness in the village or community structure. But, because of the limited attention to improvement of agricultural productivity and the broad scope of attention given to many things by the village level workers and community development specialists they tended to defer and retard the growth of basic agricultural education, research and extension organizations.

The foregoing comments should not be construed as minimizing the importance of extension or community improvement projects. The emphasis given to such efforts, however, without a source of dependable technological or substantive inputs, was a decided handicap in getting agriculture moving on a sound base in many of the developing nations.

The "Temporary Program" Syndrome

A major factor restricting attention to the research component in foreign cooperation is the attitude that has developed among the American people—and is reflected in the Congress—that technical assistance is a temporary process of short duration. Research programs, which require a reasonable degree of stability and continuity, have usually been ruled out or given low priority by administrators seeking quick and visible results.

The need to obtain annual authorizations as well as annual appropriations for the program has been used by foreign aid administrators to justify their lack of support for research. This, of course, is only a partially substantive rationale since the USDA research program has persisted for many decades under annual appropriations.

The current concept of temporariness is at variance with the beliefs and understandings of those originally concerned with the development and implementation of the Point IV program. The airgram from Secretary of State Dean Acheson of January 26, 1950, to American diplomatic and counselor officers, advising of the visit of the special Point IV review team, stated that one purpose of the team was to "discuss in all countries visited the needs, possibilities, and first steps in initiating the *long range technical assistance program* in agriculture under Point IV, through U.S. and UN, expected to begin after July 1, 1950." [Italics added.]

Research in the AID-U.S. Land Grant University Contracts

The U.S. land grant universities have been involved in a large number of contracts with AID and its predecessor agencies to provide guidance and assistance in establishing similar institutions in the cooperating developing countries. Approximately 39 U.S. land grant universities have been engaged under 95 separate contracts, to provide assistance to approximately 78 major research and educational institutions in 44 countries. More than 1,500 U.S. university staff members have worked in the less developed countries under these contract programs. Over 2,300 foreign agricultural participants have been brought to the United States for training under the land grant university contracts, and an equal number of trainees

have been supported under direct U.S. government arrangements [USAID, 1968b, 2]. This collaboration has been underway for more than 16 years.

In 1964, AID arranged with the Committee on Institutional Cooperation of the Midwestern Universities for C.I.C. to undertake a study of AID university contract projects in agricultural education and research. A summary report of this project, entitled *Building Institutions to Serve Agriculture* [C.I.C., 1968], was released in early 1969. The study also produced 19 special reports.

Although there is a general impression that the land grant universities are assisting in establishing institutions in the developing nations with combined attention to education, research and extension the major emphasis in most of these contracts has been on teaching programs. The research input has been modest or entirely lacking—present to the degree that individual U.S. specialists had an interest and opportunity to carry out selected projects. The research emphasis varies with the specific university contract, but in only a few cases is the research of a nature and scope to furnish a meaningful technological input in developing the agriculture of the country. Also, relatively little attention has been given to the role of these institutions in integrated, national agricultural research systems.

Although the majority of the Point IV programs were launched with strong emphasis on extension, a few included at least a modest research component. Dr. Frank W. Parker, as the Chief Agriculturist in the Technical Cooperation Mission in India, arranged in the early 1950s for a number of soil scientists to study the fertility status of soils and to guide development of soil testing methods and facilities. This was instrumental in changing decisions on kinds and quantities of fertilizers needed in India and furnished a base for improving fertilizer resources in the country. Dr. Parker also supplied the initiative for review and strengthening of agricultural research and education programs in India, with the study of the First Joint Indo-American Team on Agricultural Research and Education providing the guidance for subsequent collaboration by the Rockefeller Foundation and by the U.S. land grant universities [ICAR, 1955; and Propp, 1968].

The earlier attention to the research approach in India was lessened in the Second and Third Five-Year Plans, after 1955, as India turned from agriculture to emphasize industrial development. And the preponderance of non-research personnel in AID and its predecessor agencies caused special emphasis to be placed on more operational and more visible activities.

The AID Central Research Program

Lack of a sound research component within the USAID program was recognized in the early 1960s by a number of the Agency personnel, particularly by Drs. F. W. Parker and E. J. Long and their associates in the Office of Technical Cooperation and Research. A research program with special budget support was initiated in AID in 1962 and the Agency staff took the initiative for planning the Conference on International Rural Development in July 1964 in which the U.S. land grant universities, the USDA, and AID participated. The consensus of the conference was that much greater support should be given to the research component, not only directly by the Agency but also within its contracts with land grant universities.

The AID Central Research Program does not carry out research itself but provides funds for projects conducted by selected universities, the USDA, and other organizations on a variety of problems in economic development [USAID, 1968a]. This program has been guided by a Research Advisory Committee composed of leading scientists from a wide range of fields and disciplines, including agriculture. Although some initial growing pains and difficulties were experienced, due in part to the limited staff within the Agency with experience in research and to the difficulty in getting some of the participating institutions to identify with the problem-oriented requirements of the Agency, this program is emerging as a solid new technology base for the U.S. foreign aid effort. Of the 114 projects which have been provided with a total of $58.6 million through April 30, 1969, 32 projects have been in agriculture and rural development. Of the 60 currently active projects funded at the level of $43.9 million through April 1969, there are 22 in agriculture and rural development receiving $19 million, or nearly one half of the total [USAID, 1969].

The AID Central Research Program in Agriculture is broad in subject matter fields as well as geographically. It includes investigations on soil fertility, water management, cereal crop and grain legume breeding, quality improvement in wheat and sorghums, farm mechanization in Asia, control of weeds, control of vertebrate pests, the sterility method for control of the tsetse fly in Africa, land tenure, credit, prices, marketing, capital utilization, and studies in other biological, economic and social science fields.

The Role of USAID in Furnishing New Science and Technology

Although the AID Central Research Program was late in initiation, slow in getting started, is still inadequately funded, and has been underway for only six years, it is a solid step in the right direction and the new technology and information that is being generated should improve the quality and substance of future foreign aid activities. There is still uncertainty, however, about the feasibility of building and maintaining an effective support base for research and other long-range activities within an organization so strongly oriented to general economic assistance, so concerned with highly visible and short-range operational projects, and so subject to frequent reorganizations.

There is substantial merit in having a close association of technical assistance, including research, with economic assistance. But under the organization of the Agency for International Development which has prevailed since 1961 this relationship has not proved to be especially beneficial. The highly independent regional bureaus have not received effective technical inputs from their inadequate "technical" staff offices, and they have been neither responsive to nor supportive of the central Office of Technical Cooperation and Research and its successor, the Research and Institutional Grants Staff. This continuing low priority to research in AID was fully demonstrated in the reorganization of February 1967 when the technical cooperation and research activities were considered expendable and the pro-

fessional staff concerned with these functions were taken over as a major personnel resource for the new Office of the War on Hunger and shifted largely to operational programs. Most of the experienced research personnel subsequently left the Agency.

If research is to be a relevant part of the continuing foreign aid effort the technical assistance and research activities of AID should have the same budgetary and organizational support and status as the regional operating bureaus. Even when Agency-supported research projects are individually sound they will have largely "project focus" rather than program impact unless there is a more solid basic structure within the Agency from which to operate.

Another serious deficiency in the USAID effort is the failure to assess indigenous resources for generating new technology as U.S. assistance is withdrawn from cooperative programs. The agricultural research capability of the developing nations was generally overestimated when our foreign aid activities were initiated. It has received indifferent attention during the many years of cooperative technical and economic assistance. And it is now usually overlooked as steps are taken to terminate U.S. cooperative assistance in particular countries.

Decisions on withdrawal or diminution of support to individual countries are determined largely on the evaluation of such economic indices as the rate of increase in gross national product or in per capita income, or the rate of increase in overall production over recent years. The indigenous institutional capability for generation of new agricultural technology has not been recognized as an essential "self-help" resource in reaching these withdrawal decisions, even in those countries which are still largely rural or agricultural.

Chapter V

ADAPTIVE RESEARCH

There has been considerable reference to "adaptive research" in technical cooperation programs in recent years and it is evident that this term means different things to different people. It has been used to describe what is usually regarded as the test-demonstration trial in U.S. agriculture to determine how new materials or new practices will perform under specific environmental conditions. The labeling of such observation plantings or trials as "adaptive research" has tended to convey the impression among government leaders in some developing countries that a research resource base exists when actually it does not.

The task force of the Association of State Universities and Land Grant Colleges and U.S. Department of Agriculture in their report "A National Program of Research for Agriculture" [1966, 1], stated:

> Research in any field is the asking of carefully structured questions and the answering of those questions by careful methods of science. When questions and answers are of relevance to agriculture and forestry, their substance is agricultural, but the methodology is that of science at large.

There is rather general agreement that fundamental or *basic research* is designed to deepen insights and understanding into biological and physical forces, or the economic and social conditions with which we are concerned. *Applied research* is the direction or utilization of such basic and background knowledge

to the improvement or change of specific materials or conditions. *Adaptive research,* as used by the writer, involves adjustments, modifications, or changes, brought about through systematic research or "the methods of science."

In distinguishing between *applied research* and *adaptive research,* the former represents the initial direction or application of fundamental knowledge to a practical end use, while adaptive research is concerned with the further modification or adjustment of that applied result. As an example, we would consider studies into the basic biology or reproductive physiology of the screw worm, and of the effects of radiation in causing sterility or genetic changes, as in the field of fundamental science. The direction of these findings to the practical task of controlling or eradicating the screw worm involves applied research. The further modifications, such as the use of different sterilizing agents, the use of other media for rearing the larvae, or the timing of the distribution of the sterilized larvae, etc., would fall into the category of adaptive research, fitting a known technique or procedure to specific requirements.

We have had considerable experience with *adaptive research* in crop breeding and improvement programs, in suiting crops to new environments, in changing resistance or tolerance to diseases and pests, and in modifying product quality. The cooperative federal-state program of adaptive research successfully transferred the benefits of hybrid corn from the midwest to the southern states through the development of the "Dixie Hybrids." Similarly, soybean production has expanded in the United States largely because of the breeding and selection of varieties adapted to the different environments, especially to length of day, from the Mississippi Delta to the North Central states.

There is, of course, substantial transferability of crop varieties *within* latitudes. The corn hybrid U.S. 13, developed for production in the U.S. corn belt, proved to be well suited for growing in western Europe and performed well in Kashmir as well as other countries in this general latitude. Similarly, the variety Tequisate Golden Yellow Flint, developed in the co-

operative program of Iowa State College in Guatemala in the 1940s, has furnished the basic germ plasm for corn production in Thailand which has moved from a modest crop of little economic significance in 1950, to an export production of U.S. $6 million in 1959, and U.S. $50 million in 1966 [FAO, 1967]. This variety also supplied the basic stock for the "Metro" variety of Indonesia.

The widespread use in Asia of the Mexican wheats and the IRRI rice varieties has created the false impression that "basic problems of plant breeding can be effectively addressed in a single world center" [USAID, 1968a]. It would be most unfortunate if this idea prevailed since the non-sensitivity to day length of these wheat and rice varieties, which permits their suitability over a wide range of latitudes, represents an exceptional rather than a common characteristic.

The restraints to mobility in other crops still persist. And a pertinent example is the experience of the Rockefeller Foundation in the attempt to boost corn yields in the Puebla region in Mexico. The results of a series of trials in this region to combine essential inputs to maximize yields indicated that a major limitation was the lack of varieties or hybrids that were responsive and capable of out-performing the local varieties. Few of the materials produced in the cooperative corn breeding program conducted over the previous 20 years at Chapingo—less than 100 miles away—were sufficiently well adapted, with the yield capacity required, for the Puebla conditions. It is essential to temper expectations from the few years of experience with the new wheats and rices with the longer record of results of photoperiod research with many economic crops.

The protective research required to overcome or minimize destruction from pests and diseases is also a form of adaptive research which should be conducted as close as possible to the specific farming regions. This will undoubtedly become more clearly evident after the rapidly-spread new wheat and rice varieties have had a few more years of exposure to indigenous races or forms of diseases and pests in the many countries of Asia.

International Wheat Improvement

The process of adaptive research, under guidance of trained scientists to reshape and modify materials and practices to fit specific local growing conditions, was utilized by the Rockefeller Foundation in the cooperative agricultural sciences program initiated in Mexico in 1943. The accomplishment in wheat improvement in Mexico and the subsequent impact of the "Mexican wheats" in South Asia has been well publicized. But, perhaps the progress is more generally recognized and appreciated than is the process.

When the cooperative effort was started with the Mexican Ministry of Agriculture wheat yields in Mexico were low and uncertain because of recurring epiphytotics (epidemics) of stem rust. Prompt attention was given to breeding and selection of varieties with resistance to the disease. The two first such varieties, Supremo and Frontera, were selected from hybrid materials furnished by Mr. E. S. McFadden of the USDA, who was then located at the Texas Agricultural Experiment Station. These hybrids obtained their resistance from the variety Hope, which McFadden had developed in the late 1920s by crossing the spring wheat variety Marquis with Yaroslav emmer.

The Supremo and Frontera varieties, released in Mexico in the fall of 1948, were seriously damaged by the new Race 15-B of stem rust in the summer of 1951. But other selections developed in the Mexico breeding program from parental lines supplied by Mr. Burton, an English plant breeder working in Kenya, proved to have resistance to Race 15-B. Dr. N. E. Borlaug, the Rockefeller Foundation plant breeder in Mexico, has utilized germ plasm from the U.S., Kenya, Australia, and elsewhere in crosses with local Mexican varieties to continuously upgrade the disease resistance and yielding ability of new wheats adapted to Mexico's wheat growing regions.

The current group of semi-dwarf "Mexican wheats," which have proved to be so broadly adaptable to conditions in Latin America, Africa, the Near East and South Asia, derive their short stature and high yielding capability from the "Norin" wheats introduced into the U.S. from Japan in 1946 by Dr. S. C. Salmon of the USDA, as discussed earlier in this paper.

A systematic adaptive research and training program has guided the exploitation of the semi-dwarf, high-yield potential on a worldwide basis. In 1962, when the Near East Wheat and Barley Project of the Food and Agriculture Organization received a special grant of $100,000 from the Government of the Netherlands, Dr. Borlaug was asked to join Dr. Jose Vallega, Director of the Plant Production and Protection Program for FAO, in a review to determine ways to strengthen the wheat and barley improvement program in the Near and Middle East. From this review emerged the recommendation that in-service training experience should be furnished for young scientists from the Near and Middle East countries to work for a period of nine months in the cooperative wheat improvement program in Mexico.

Arrangements were made for the training project to be sponsored by the FAO, with full collaboration of the Ministry of Agriculture of Mexico, and with financial assistance from the Rockefeller Foundation. By 1968 training had been furnished to more than 50 participants from Pakistan, India, Afghanistan, Nepal, Iran, Iraq, Jordan, Syria, Turkey, Egypt, Sudan and Ethiopia. The trainees not only became fully familiar with modern techniques for wheat improvement research but also introduced some of the high yielding varieties and hybrid combinations from Mexico into the wheat research programs of their respective countries.

In addition to the training program, a cooperative Near East-American spring wheat nursery program was established in 1962 for the systematic evaluation of 25 of the most promising spring wheat varieties used in the Near East, Mexico, Colombia and the Argentine. These tests, under the local supervision of the young scientists trained in the cooperative Mexican program, are conducted under varying rainfall and irrigation conditions, with or without fertilizers. The Near East variety testing program was combined with the inter-American nursery trials, which had been initiated in 1960, into a single *International Spring Wheat Yield Nursery* in 1964 when results were obtained from 34 locations in 23 countries in the Americas and from South Africa through the Near and Middle East countries to Australia [Krull, 1968a]. The nurseries were grown at alti-

tudes from 226 meters below sea level in the Jordan Valley to 3,058 meters above sea level in Ecuador, and from latitudes 35° south to 45° north.

The Mexican wheats, with their non-sensitivity to length of day, performed well under a wide range of conditions in tropical and subtropical regions. The package of practices—including the selection of the right variety, planting methods, fertilizer levels and water management—as developed through the research in Mexico, also proved to be generally suited for conditions in the Near and Middle East countries, in Africa and in South Asia.

It was from the cooperative Near and Middle East wheat nurseries that the two lines from the Mexican cross 8156 (Penjamo sib x Gabo 55) were selected—to become the outstanding varieties which have so dramatically changed the food grain situation in India, Pakistan, Turkey and Afghanistan in recent years. It is estimated that during the 1967-68 crop season the varieties and lines originating in Mexico were grown on about 10 percent of the wheat acreages of the Near East and South Asia. The acreage is expected to increase to 15 to 17 percent in 1968-69 [West, 1969]. Some adaptation or modification has been required, however, including the breeding of varieties with white grain color for India and Pakistan to meet the preference of growers and consumers in those countries.

It is important to recognize the importance of capable "local" research leadership in the expanded international dimensions of the wheat program. The provision of a plant breeder by the Rockefeller Foundation to strengthen wheat research in India in 1964, and by the Ford Foundation in Pakistan in 1965, were most significant factors in accelerating the evaluation and use of the introduced materials and methods in these countries.

The international wheat research program is a replica of the pattern followed for several decades in improvement of wheat, corn and other crops in the U.S. The utilization of international collections of germ plasm, the provision of capable scientific leadership for planning and prompt reporting of results, and the deputation of key research personnel to the participating nations (or states) are common elements.

International Programs on Corn, Other Food Crops, and Livestock

The early expansion to international dimensions of the U.S. advances in corn improvement has been discussed in connection with the cooperation in establishing hybrid corn materials and practices in Europe in the late 1940s. The research-based corn improvement project of the Rockefeller Foundation and the Ministry of Agriculture in Mexico also benefitted from the knowledge of genetics and plant breeding techniques of U.S. agricultural science. This program, however, received less direct help from U.S. germ plasm stocks which have been selected and adapted to the day length conditions of the temperate zone.

In addition to the independent collection of maize strains developed by the Foundation personnel in Mexico, the special project supported by the U.S. National Academy of Sciences/ National Research Council [Clark, 1956] provided the corn germ plasm bank of more than 12,000 collections which have been composited into about 200 lines or races. These materials are maintained through the cooperation of the Rockefeller Foundation and the local governments in Mexico, Colombia and Brazil, as well as in the U.S.

The corn improvement research in Mexico supplied the base for the cooperative Foundation programs initiated in Colombia in 1950, in Central American countries in 1954, and in India in 1956. Subsequent collaboration in Kenya, Nigeria and Egypt, together with the outreach of the program from India into Thailand and the Philippines has extended the cooperative corn improvement program around the world through a systematic adaptive research process.

The cooperative potato improvement project in Mexico similarly was initiated as an adaptive research project drawing heavily on the hybrid materials produced by USDA plant breeders at Beltsville, state experiment station scientists at Cornell and other states, and the Potato Introduction Station at Sturgeon Bay, Wisconsin. The heavy natural infestations of *Phythopthora infestans* at the Toluca, Mexico, station makes it possible to isolate varieties with resistance to the late blight disease caused by

this organism. This project has not only furnished Mexico and other countries with the benefits of the coordinated U.S. potato-breeding research program but has also added an important disease resistance dimension to the U.S. program.

The improvement of sorghums and millets for the developing nations was given an initial impetus in the project started in the cooperative program in Mexico, and was expanded greatly in the cooperative research of the Rockefeller Foundation and the Government of India which was started in 1956. The germ plasm collection of the U.S. furnished the nucleus of the breeding stocks which have been enhanced subsequently by extensive collections in India and Africa. This comprehensive and valuable resource of breeding lines is maintained in India as well as at U.S. plant introduction centers. Close consultation with U.S. research workers on sorghum and millet improvement has been of mutual benefit to the cooperative programs in India and other developing nations and in the United States.

Livestock improvement research has been conducted cooperatively for many years particularly with countries in which serious disease hazards exist. However, the research on foot and mouth disease, African swine fever and other diseases has been of concern primarily to protect the U.S. industry.

Most of the cooperative efforts to improve livestock production in the developing nations have involved test-demonstration approaches, to apply directly the existing advances in breeding, nutrition, management and disease control to specific environments. There is still a general tendency to follow this "extension" approach, through establishment of pilot production centers for beef cattle, dairy enterprises and swine.

Animal scientists experienced with problems of production in tropical environments are fully alert to the importance of adaptive research. Although considerable progress has been made in transferring large scale broiler or egg production practices to developing nations, utilizing stocks or lines bred in temperate zone countries, there is need for supporting studies on feedstuffs, management practices and diseases or pests. Several nations and the FAO have supported research for livestock improvement, but much of the attention has been on diseases,

along the pattern of the United Kingdom in India and Pakistan and in the East Africa Veterinary Research Organization.

Adaptive Research Supported by USAID

The research conducted by the USDA under AID support on cereal crop improvement in Africa adds a solid dimension to the cooperative corn and sorghum improvement research of the Rockefeller Foundation. The USDA-directed research on improvement of grain legumes in Asia and on use of the sterility method for tsetse fly control in Africa fall into this same category.

There is, perhaps, some question whether these latter two projects should be classed strictly as "adaptive research" since they involved more than the simple application or use of standard materials and methods. The corn improvement research in Kenya was modified by development of intervarietal hybrids rather than the customary four-way crosses, on the basis of background research done previously in the U.S. by the geneticist in charge of the project. Intervarietal crosses are less well suited to temperate zone agriculture because of the limited base of corn germ plasm adapted to temperate zone conditions. Similarly, the research on tsetse fly control involves special studies on the biology of the insect as well as on the *chemo*sterilants. And the grain legume project requires new initiatives since the specific crops are not common in the U.S. and most of the germ plasm materials have been collected from the developing countries where these crops are grown as food grains.

Adaptive Research Teams

Dr. F. F. Hill, while Vice-President of the Ford Foundation in 1965, urged that the increase of food production in the developing nations be accelerated through provision of "emergency research teams" to guide introduction of new technology. This procedure is being followed in Pakistan, with Ford Foundation support for employment of Dr. Ignacio Narvaez, the Mexican

plant breeder who went to Pakistan in 1965 to lead the adaptive research program for the widespread use of the variety "Mexipak" and other Mexican wheat selections in Pakistan's intensive agricultural production campaign. The Ford Foundation also is supporting professional leadership for adaptive research for rice improvement in West and East Pakistan, Indonesia and other Asian countries, drawing on the varieties and technology of the International Rice Research Institute in the Philippines.

Adaptive Research Projects and National Research Systems

The adaptive research programs of the Rockefeller and Ford foundations and AID apply internationally the national pattern of problem-oriented, multidisciplinary research of the USDA and the state agricultural experiment stations. The program direction and coordination is furnished by scientists operating from a central or "national" level with substantial flexibility in carrying out research in specific cropping or problem areas. The Rockefeller Foundation program has the most extensive experience in expanding into international dimensions. As the Foundation's cooperative research expanded from Mexico to Colombia to Central America to Chile and to India, the programs retained a high degree of bilateral collaboration on a "national program" basis. Although there was considerable cooperation and spillover into other countries, particularly in Latin America, the internationalization of the research was accelerated when the International Food Crop Improvement Program was established in 1959, providing new dimensions for wheat, corn and potato improvement.

A primary factor in the effective expansion of the adaptive research program has, of course, been the initial leadership supplied by the research staff in Mexico. A second pertinent feature has been the linkage with competent scientific capability in each of the collaborating countries, supplied either by the foundations, as in the case of the adaptive research teams, or by local personnel who have substantial organizational and bud-

getary stability. This type of professional linkage internationally is, of course, comparable to the USDA collaboration with scientific colleagues in the state agricultural experiment stations. And, as the USDA-supported research would be seriously handicapped without competence in the cooperating states, the international programs will be restrained so long as there is limited competence in the developing nations.

The individual cooperative food crop improvement projects can be most effective pattern makers in guiding the strengthening of national agricultural research systems. They not only demonstrate the merits of problem-oriented interdisciplinary research but also furnish in-service training for young scientists. The extent to which these projects will serve in this institution-building role, however, is still to be determined. In the recent intensive efforts to increase food grain production there has been a strong *project orientation,* with activities directed to the immediate task of increasing national food supplies. There has been only limited attention as yet to the utilization of the adaptive research project as a nucleus to strengthen national research capability.

Stronger national research systems will not automatically arise from emergency adaptive research projects. It is essential that (1) special attention be given to training of local personnel, and (2) an organizational base be structured to enable local personnel to carry on after the adaptive research team members depart. The latter aspect has not been given the support and attention it deserves.

Chapter VI

SPECIALIZED AGRICULTURAL RESEARCH INSTITUTES

The new rice and wheat production technology in Asia in the past three years has directed attention of technical and economic assistance organizations toward specialized regional or international research centers as the primary sources of new technology for international agricultural development.

The concentration of research personnel from different scientific disciplines at specialized field stations, centers or institutes has facilitated development of new agricultural technology in a number of developing countries as well as in the agriculturally advanced nations. There is a varied base of experience to be assessed, therefore, in determining the short-run as well as longer range role of the specialized research centers in promoting international agricultural and economic growth.

U.S. Experience

The regional Bankhead-Jones laboratories, developed in the late 1930s and discussed earlier in this paper, are problem-oriented, multidisciplinary research centers devoted to special aspects of agricultural development. Some of these institutions are strongly commodity-oriented, concerned with improvement of pastures, vegetables, soybeans, sheep, poultry, etc., while others address non-commodity areas such as soil salinity and nutrition.

The Hawaiian Sugar Planters Experiment Station and the Pineapple Research Institute in Hawaii, each supported by in-

dustry, are widely recognized commodity-oriented, multidisciplinary research centers.

There has been a rather continuous development of other specialized agricultural research laboratories or centers in the United States, largely under federal support, for a variety of problem areas such as soil and water management; boll weevil and grain insect control; plant introduction, evaluation, and maintenance; and other fields. These intensive attention centers enrich the more dispersed cooperative state-federal research programs and they have an important role in the total U.S. agricultural research system.

Specialized Research Institutes in Developing Nations

The British used the commodity research institute approach in a number of their colonies, with the Rubber Research Institute established in Malaya in 1925, together with the companion National Rubber Producers Research Association in England and the Tropical Agricultural Research Institute in Trinidad. Research Institutes were set up in India concerned with sugarcane, rice, jute and other crops. In West Africa, regional research institutes were established for improving production of rubber, cocoa and oil palm.

The Empire Cotton Growing Corporation, an independent body supported by the cotton industry and the Government of the U.K., has a most impressive record of accomplishment in the former British territories. As stated by Bunting [1963, 515]:

> For more than forty years the Corporation has provided a home-based service for research on the cotton crop in certain overseas territories, at the invitation of their Governments and in collaboration with their own agricultural services. Its staff numbers fewer than 50 scientists, and its budget, two-thirds of which comes from contributing Governments and the rest from the interest on an initial capital grant from the Treasury, is less than £250,000 a year, but it has a first-class record of fundamental and applied studies. Since 1921 the total production of cotton in the territories in which it now works (Sudan, Uganda, Tanganyika, Nigeria, Kenya, Nyasaland, the West Indies and Aden) has been

multiplied seventeenfold: the Corporation has played a notable part in this great achievement. Further, its staff has been able to contribute to the advancement of agriculture generally in these territories, and in some it has represented, in times of rapid change, not only a source of urgently needed specialists for secondment, but almost the only source of continuity in research. Through its scientific committee and consultants the Corporation has firm links with higher education and research in agricultural science in Britain as well as with the appropriate official organizations.

The Netherlands has followed the pattern of specialized research institutes, characteristic of the organization of the agricultural sciences at Wageningen, in setting up research for agriculture in Indonesia. These have persisted in Indonesia, with a high degree of autonomy among the institutes concerned with the individual estate crops and with agriculture generally.

The Institute Nationale pour l'Etudes Agronomique de Congo (INEAC), established in the Republic of the Congo by the Belgian Government in 1935, was achieving widespread recognition as one of the world's outstanding research organizations for guidance of tropical agriculture at the time of independence of the Congo, when the research program was seriously decimated. The INEAC staff competence covered a wide range of disciplines, including the social sciences, and the research was conducted on a national system basis with field stations in the different soil and climatic zones of the Congo.

The International Agricultural Research Institutes

Research centers or programs established in the countries of Africa and Asia were concerned in most cases with guidance of the production of export crops. They were focused strongly on the problems of the individual country or region, with little or no specifically planned "international" dimension.

The Inter-American Institute for Agricultural Sciences, established with central headquarters at Turrialba, Costa Rica, in 1943, was among the first research centers organized to assist countries of a region with general agricultural development.

The International Rice Research Institute, established

jointly by the Ford and Rockefeller foundations and the Government of the Philippines at Los Baños in 1962, also was designed from the beginning as a science and technology resource with international dimensions, to extend cooperation beyond the "rice bowl" countries and worldwide. The multidisciplinary staff of about 25 scientists also is international, with personnel from many of the developing nations, from Japan and the United States.

The IRRI is concerned not only with a comprehensive program of basic, applied and adaptive research but also with training programs for scientists and for extension workers, with sponsoring of workshops or special conferences, and with provision of documentation and information exchange services.

The International Maize and Wheat Improvement Center (CIMMYT), which was formally established in Mexico in 1966, is an autonomous non-profit, scientific and educational institution incorporated under the law of the host country and governed by an international board of directors from nine countries. The Center had been set up on a less formal basis by the Rockefeller Foundation and the Ministry of Agriculture of Mexico in 1963. The high yielding "Mexican wheats" were developed in the earlier bilateral cooperative program of the Foundation and the Ministry and so were not a product of CIMMYT but actually supplied much of the impetus for the subsequent establishment of the Center.

The Rockefeller Foundation and the Ford Foundation are collaborating in setting up tropical research institutes in Africa and in South America. Planning for the institute to be located near the University of Ibaden in Nigeria was initiated in 1963. The formal agreement for the institute to be developed in the Cauca Valley area of Colombia, near Palmyra, was consummated in 1967. The Kellogg Foundation is also participating in the institute in Colombia.

While the IRRI and CIMMYT are organized primarily around the principal food grains, the institutes in Nigeria and Colombia will be broader in scope, with attention to a wide range of food crops, soil and water management, and livestock.

Another center initiated with Rockefeller Foundation support as an international research and training resource is the

Dry Lands Research Institute at the University of California at Riverside, established in 1964.

Relationship of the Specialized Institutes to National Agricultural Research Systems

The extensive publicity given to the "Mexican wheats" and to the "miracle rices" in the past three years has generated the widespread beliefs that (1) the food-population problem is resolved, (2) the available agricultural science and technology resource for wheat and rice improvement is adequate for current needs, and (3) the future international requirements for agricultural technology can be supplied through three or four specialized research institutes.

However, those who are at the forefront of the new technological developments are the first to recognize that the recent advances are, as stated by Dr. Robert F. Chandler [1968, 41], Director of the International Rice Research Institute:

> . . . but a stop-gap arrangement to allow time for population control to become widely accepted, for industry to utilize natural resources, for education to become more widespread, thus for true economic development to occur.

And Dr. N. E. Borlaug [1969], who guided the development of the Mexican wheats, states:

> The international centers are not substitutes for sound, aggressive national programs. The international centers can and should be involved primarily in long-time research projects and as 'clearing houses' and catalysts for the national programs.

The international centers or institutes are important institutions in accelerating the development of improved agricultural technology. But it is important to recognize both their potentialities and their limitations. Although they will be most important vehicles for developing new basic concepts or principles for improvement of agriculture in tropical regions the increasingly critical adaptive and protective research will require com-

petent attention to localized agricultural conditions in the individual countries.

The limitations of the specialized centers in this regard are fully evident from the lack of depth of staff within a given scientific field. We would not expect a small staff of two or three scientists in a given discipline—be they plant breeders, entomologists, plant pathologists, soil scientists, or other agricultural specialists—to embrace the complex of problems encountered in their specialties over any substantial region. International agricultural growth and development would be rendered a serious disservice if we assumed that a handful of specialists—no matter how dedicated and able—could continue to generate the type of widely applicable new technology necessary for sustained boosts in productivity over broad geographic areas.

In this regard there is considerable divergence of viewpoint with respect to bilateral versus regional or international patterns of technical collaboration. This was evident from the meetings in 1967 of the Development Assistance Committee of OECD. At the July 1966 meeting in Washington of the Development Assistance Committee, to stimulate greater interest of the member nations in the world food problem, it was agreed that a follow-up meeting should be held in the Spring of 1967 to consider specific prospects for collaboration [OECD, 1968].

For this conference, the U.S. delegation presented a proposal for strengthening international collaboration in adaptive research with special emphasis on (1) *World Centers* patterned after the International Rice Research Institute, (2) *Regional Centers* to be concerned with problems in the major ecological regions, and (3) *National Centers* for attention to localized problems. Each of the proposed types of centers would provide for research and for training of researchers and extension specialists. The response to the U.S. proposal was sufficiently favorable to encourage a follow-up conference which was held in late October 1967. This meeting, however, failed to identify specific problem areas or world or regional centers acceptable for mutual support by the DAC member nations.

A number of the nations with a long history of research in developing countries, such as that of the United Kingdom in

South Asia, the Far East, and Africa; the Netherlands in Indonesia; Belgium in the Congo; and the French in Africa; have had substantial experience with the centralized institute approach as well as with other patterns of support for research. There was an evident reluctance on the part of the European nations to commit resources to long-range core support for world or regional centers, and a strong preference to retain maximum flexibility in collaborating via the bilateral pattern.

For the longer term, the significance of the specialized international centers will depend upon (1) their versatility in responding to critical problems of regional or international significance, (2) the quality of their pioneering or background research to supply innovations suitable for adaptation by national research organizations, and (3) the rapidity of development of capable national systems in the individual countries.

Chapter VII

STRENGTHENING NATIONAL RESEARCH SYSTEMS

The growing awareness of the significance of new technology in agricultural growth is shared by natural scientists, social scientists, and economists. The views of prominent economists are exemplified by Mellor's conclusions that research to develop new technology should have priority in timing, and Schultz's assertion that building of indigenous research capability has been too long delayed in cooperative technical assistance programs.

Hill emphasizes the importance of both technology and the organizational base for generating it. In addressing the National Association of State Universities and Land Grant Colleges, Hill stated [1966, 3]:

> If the developing countries are to achieve a generally high level of economic well-being in the years ahead, including sufficient food to meet the needs of their rapidly increasing populations, they must move in two directions. First, they must move in the direction of greater control of human fertility. Second, they must place their agriculture on a modern scientific basis.

In assessing the institutional structure and national capacity for research Hill said [1966, 6-7]:

> Why has improved production technology for food crops suited to the needs of the developing countries not been produced during the past twenty years or more? Some, although by no means all, of these countries have substantial numbers of well-trained scientists, particularly in South and Southeast Asia and Latin America. But there are few well-organized agricultural research institutions and programs in developing countries of the kind that laid the

basis for the revolution in agricultural production that has occurred since the turn of the century in Western Europe, the United States, Canada, Japan, and Australia, and for agricultural revolutions of the kind that are now well under way in Mexico and Taiwan. In all these countries, teams of highly trained scientists, well-balanced as to disciplines, were provided with good research facilities, adequate operating budgets and put to work developing improved methods of producing a specific crop such as corn, wheat, rice, or potatoes. They and their successors stayed at the job until they got results. Performance was measured in terms of increased national yields. Since the turn of the century, corn and rice yields in the United States and wheat yields in Australia have more than doubled; and rice yields in Japan and wheat yields in the United Kingdom and the United States have increased by between 75 and 100 per cent.

Research organizations and programs concerned with the production of food crops, such as those that have long been in operation in developed countries such as Japan and the United States are what is needed in the developing countries to start agriculture moving, and it is the goal toward which a number of these countries are working. But few of them have yet achieved the organization, the financing, the level of group competence and the outlook on the part of their scientists necessary to produce significant results. Research staffs frequently are not well-balanced as to disciplines and often lack good research facilities and adequate operating budgets. All too frequently their efforts are widely diffused among a variety of projects rather than sharply focused on finding ways of revolutionizing the production of a specific food crop, such as wheat or rice. In some cases, the research in which staff members are engaged has little bearing, directly or indirectly, on the problem of finding answers to the country's food problems. In a country not confronted with a food crisis, this may not matter. But in countries facing actual or potential shortages of food, it can be tragic.

The new wheat and rice production technology puts the food supply team a leg up in the food-population race. This temporary lead time will undoubtedly be brief but such time as is available before the next famine threat should be used to strengthen the technological base to meet it. *The next time around the needs will have to be met in larger part by national research capabilities.*

Protective Research

Much has been said, in this paper and elsewhere, about the potential hazards of indigenous pests and diseases to the expanding acreages in Asia planted to the introduced wheats and rices. But this is a real threat and the risks cannot be overemphasized. The present respite in the food supply situation may well be short-lived if protective research attention proves inadequate.

We know from experience in the U.S. that the rapid introduction and widespread use of new crop varieties accelerates the biological dynamics of crop disease-host plant relationships. This also was well demonstrated in Mexico where the initial rust resistant varieties of wheat selected by Rockefeller Foundation personnel were knocked out after three years of commercial growing. Later selections, with resistance introduced from varieties from Kenya, soon experienced the same fate as the result of another race of stem rust. The emergence of Races 15-B, 49-B, 139, 29 and 48 posed serious continuous threats to the new wheats developed in Mexico And the successful combating of these and other races was accomplished only through continuous breeding research *in Mexico* to evolve resistant varieties fitted to local environments.

The Mexipak variety of wheat is susceptible to certain races of rusts in Mexico and to Race 42 of stem rust which occurs in Pakistan and other countries of the Middle East and South Asia. The rice variety IR-8, introduced into Malaysia and released for growing in 1966 as the variety "Ria," proved to be highly susceptible to local races of the blast disease *Piricularia oryzeae*. By 1968 it was being used as the susceptible check variety in the blast disease nurseries in that country. IR-8 also is highly susceptible to a bacterial leaf disease in Indonesia where the yield potential of this variety has been reduced substantially from its outstanding performance when first introduced.

The protective research to forestall serious epidemic losses in rice, wheat and maize cannot be supplied effectively by the limited plant breeding and plant pathology capability of the IRRI and of CIMMYT but must be conducted largely by individual countries. U.S. agriculture did not depend upon the

single center for cereal rust research at the University of Minnesota, or on the Dominion Rust Laboratory at Winnipeg, Canada, to provide the solution for the outbreak of stem rust Race 15-B and other virulent races which have attacked the wheat crop from Mexico through the U.S. and into Canada. These problems were met by strengthening breeding and pathology research throughout the region.

Agricultural Research Costs and Returns

The question is frequently raised as to whether developing nations can afford the investment in national institutions for agricultural science and technology or whether the fragility of some national governments precludes effective progress in such institution building. In this regard it is well to remember that the basic structure for our U.S. national system of land grant colleges and for the USDA was established in 1862, when our nation was engaged in a vigorous Civil War and our national treasury was stressed from the costs of that war. As stated by Hill [n.d., 1]:

> Even by standards of the times, the United States was still an underdeveloped country in 1862, with a population of less than 35,000,000, predominantly rural holding title to (if not actually occupying) an area of some 3,000,000 square miles. Then as now, the development of a country depended upon the education of its people, its institutions, and the state of the industrial and agricultural arts. John Lane's steel moldboard plow and Cyrus McCormick's reaper were less than 35 years old. Von Liebig's basic studies in plant physiology had been reported only 20 years earlier. Mendel's classic experiments in genetics had not yet been published, and Pasteur's contributions to microbiology were just beginning. Although substantial progress had been made in agricultural practice during the preceding century, particularly in England through the efforts of such men as Arthur Young and Jethro Tull, progress in both agriculture and industry was still almost entirely dependent upon trial and error with little understanding of cause-and-effect relationships.

The international reservoir of *potentially applicable* science

and technology for agriculture is much greater today than it was a century ago. Nations willing to make substantial investments to extend tarmac runways to accommodate new and larger international jet aircraft, and for development of national television systems can well afford the relatively modest funds necessary to strengthen research capabilities for modernization and steady growth of their agricultural economies through adoption and use of such international scientific resources.

Estimates have been made of the returns from investments in agricultural research, based on studies of specific advances. Griliches [1958] calculated that the return on the funds invested in the development of hybrid corn and related innovations provided a return of 700% annually. A study by Arditto-Barletta [n.d] showed that from 1943 to 1963 Mexico received an annual benefit of 290% for every dollar spent on the cooperative corn and wheat improvement research program.

The increased productivity of rubber in Malaysia, to which the improved clones and production practices evolved by the Rubber Research Institute have contributed, has maintained the viability of that industry during periods of depressed rubber prices.

The improved sugarcane 2878 POJ, developed in Java, has had a strong influence on sugar production around the world. It has been stated that,

> The yield increase, together with the automatically decreasing cost price, in 1928, when ⅔ of the cane was planted with 2878 POJ [in Java] paid back in one year all the costs which had been spent for more than 40 years of sugar research including 6% compound interest [Handojo, 1969].

Estimates have been made of the value of the new wheat and rice production technology in Asia. It has been suggested that the benefit from increased rice production alone reaches a level of $500 million [Chandler, 1968]. The diminishing of hunger and the contributions to economic and political stability are even more significant.

There are numerous other examples which could be cited, such as the reduction of losses to livestock from the screw worm in the United States, the minimizing and elimination of other

animal and plant pests and diseases, together with the steady increases in agricultural productivity. A rich source of specific information on such losses, most of which were subsequently brought under control through research, is the record of annual presentations by the Agricultural Research Service of the USDA before the House and Senate Subcommittees on Appropriations.

Planning National Research Systems

The initial step in strengthening national research capabilities is the recognition by national political and administrative leadership of the importance of this resource for economic development. Leaders of a number of countries in Asia are taking positive steps to assess and strengthen their agricultural research capabilities. This type of activity has been underway in India since 1955 [ICAR, 1955]. The Government of Pakistan, with the cooperation of USAID, arranged for a review of the agricultural research capabilities in that country in February-April of 1968 [Pakistan, 1968]. The Government of Malaysia arranged for a similar review in May-June [Moseman, 1968]. The Parliament of Malaysia on February 13, 1969, passed the bill establishing the Malaysian Agricultural Research and Development Institute as the organization responsible for all agricultural research (except rubber), throughout the country [MARDI, 1969b].

The Government of Indonesia, following-up on one of the recommendations of the Workshop on Food, which was sponsored by the National Academies of Science of the U.S. and Indonesia in May-June 1968 [LIPI, 1968], arranged for review of its agricultural research organization and programs by an Indonesian-American team in June-July 1969. The Joint Commission on Rural Reconstruction (JCRR), in Taiwan, requested the International Rice Research Institute to conduct a review in depth of the crop research capability in Taiwan, with special emphasis on rice. This was done in May 1969. The Office of Rural Development in Korea also has had a special interest since 1965 in improving its agricultural research competence.

The foregoing recent initiatives, which are matched by similar interests in the nations of Africa and Latin America, suggest that leaders of these countries have perhaps as much concern about the building of their national agricultural research capabilities as do the leaders of the "donor" organizations providing technical and economic assistance.

There is a divergence of opinion about the need for national research capability in some of the smaller developing nations, with the establishment of regional research centers, each serving several countries, proposed as an alternative. Steps are being taken to develop additional regional centers in Asia through the auspices of SEAMES, the Southeast Asia Ministers of Education Organization.

The international tropical agricultural research centers, including the IRRI in the Philippines and CIMMYT in Mexico, together with those being established in Nigeria and Colombia will of course, continue to furnish strong regional and international support. And, although these international centers cannot meet the specific national or local needs for research they will modify the nature of programs and organizations required in individual countries and will permit an orderly phasing and evolution of national systems. Stronger initial emphasis can be placed on adaptive, protective and applied research within each country, with emphasis on basic and fundamental studies, postponed until later.

Scope and Complexity of National Organizations

Agriculturists in the developing nations, as well as in the agriculturally advanced nations, have questioned the applicability of the U.S. agricultural research system to the needs of developing nations—particularly the smaller countries. It would, of course, be neither feasible nor desirable to attempt to transplant the U.S. organizational pattern, or that of any other agriculturally advanced nation, in its entirety. The basic structure, however, with strong support and participation by the national government, together with the dispersed federal and state experiment stations in the various agricultural regions, furnishes an operable pattern that has proved effective not only nationally but internationally.

The size of the organization, the number of regional or field research centers, and the complexity of the research system will of course depend upon the scope and diversity of the agriculture of the given country. While the specific organizational structure should be suited for the individual country, the basic components or elements of such a structure normally should include the following:

(1) a strong national center for background research and for conceptual and coordinating leadership for national and regional projects. The Beltsville Research Center provides this resource in the U.S., and similar national headquarters at Chapingo, Mexico; Tibaitata, Colombia; La Molina, Peru; La Platina (Santiago), Chile; and the Indian Agricultural Research Institute near New Delhi furnish similar "national headquarters" services in those countries;

(2) regional centers for adaptive research and specialized attention to the agricultural requirements of the major cropping regions of the country. In the U.S. the federal field stations, together with selected state agricultural experiment stations serve as regional headquarters for specific research projects;

(3) localized research and/or verification and testing stations designed to fit innovations to specific soil and climatic conditions. In the U.S. this component is represented primarily by the branch stations of the state agricultural experiment stations.

The concentration of competent scientists from various disciplines at the national headquarters will ensure most effective use of scarce talent and specialized equipment, in the same way that specialized research institutes make most efficient use of manpower and laboratory-field station resources. The level of competence at the regional stations should be similar or about equal to that of the central headquarters, but with the mix of scientific disciplines determined by the nature and complexity of the problems of the region. The competence at the localized field stations should be of the B.S. degree level of training at the beginning, with upgrading to the M.S. and Ph.D. level in time, as has occurred in the branch experiment stations in many of the states of the U.S.

There is some difference of views with respect to the concentration of scientists at a given location as contrasted with their dispersal to a number of sites in an agricultural area. The desirability of concentration is clearly evident if we accept modern science and technology as characterized by multidisciplinary teamwork attention to the numerous interrelated problems facing the farmer. This has been the experience not only in the U.S. but also in the Rockefeller Foundation programs. In Colombia, for example, the Foundation personnel were located initially at both Bogota and Medellin when the cooperative program was started in 1950. After a few years the entire Foundation staff was concentrated in Bogota, working out to the branch stations from that headquarters. Similarly, the initial dispersal of staff members of the U.S. universities cooperating in technical assistance under AID contracts in India among a large number of Indian institutions resulted in some progress in carrying out specific local projects, but made only a limited contribution to the longer term reshaping and strengthening of the research institutions. The subsequent concentration of staff for assistance to the new agricultural universities has accelerated the building of the national education-research capability.

The location of the national headquarters requires special attention. In theory, it would be desirable to have the central headquarters in the major agricultural area of the country. In practice, however, it has proved essential to have the major research center relatively close to the seat of the national government, to ensure effective communication between the leaders of the research programs and the political-administrative leadership of governments concerned with national planning, budgets, etc.

The experience with the rapid application of the new wheat and rice production technology in Asia demonstrates the importance of support from top government leaders for these technologically-based, intensive agricultural production programs. As agriculture is modernized, government planners and budgetmakers should be constantly aware of the potentials of new technology to enhance productivity levels in modifying the agricultural economy. The central research station should,

therefore, serve in a true sense as the technical arm of the Ministry of Agriculture. The station should be near enough to the capital city to facilitate communication, yet sufficiently distant to avoid excessive interference by nonprofessional visitors.

A Pattern for Problem-Oriented, Multidisciplinary Research

The exact organizational structure should be designed to fit the needs of the given country. There are numerous ways to assemble scientific talent and a national agricultural research organization should accommodate an interdisciplinary, problem-oriented approach. The organization should have a high degree of organizational stability but sufficient operational flexibility to permit shifts in emphasis on major and emergency problems as they arise.

One organizational pattern which might be modified to meet specific national needs or priorities is that proposed for the Malaysian Agricultural Research and Development Institute, as follows [MARDI, 1969a, 3-4]:

A. Crop Improvement Research Division
   a. Oil Palm Research Branch
   b. Rice Research Branch
   c. Feed and Fodder Crops Research Branch
   d. Vegetable Crops Research Branch
   e. Tree Fruit and Beverage Crop Research Branch
   f. Cocoa and Coconut Research Branch

B. Animal Improvement Research Division
   a. Animal Nutrition Research Branch
   b. Poultry Research Branch
   c. Meat Animal Research Branch
   d. Dairy Research Branch
   e. Inland Fisheries Research Branch

C. Soils, Water and Engineering Research Division
   a. Soil Classification Branch
   b. Soil Fertility and Management Research Branch
   c. Water Management Research Branch
   d. Agricultural Engineering Research Branch

D. Crop Protection Research Division

a. Insect Pest and Disease Control Research Branch
b. Pesticide Materials Research Branch
c. Rodent and Bird Control Research Branch
d. Weed Control Research Branch

E. Crop Utilization and Food Technology Research Division

a. Processing and Utilization Research Branch
b. Food Technology Research Branch
c. Crop Quality Analysis Services

F. Economics and Statistics Research Division

a. Production Economics and Farm Management Research Branch
b. Marketing Research Branch
c. Experimental Design and Statistical Services
d. Agricultural Policy Branch

The above organizational structure, revised slightly from that initially proposed in the "Report for Agricultural Development in Malaysia" [Moseman, 1968], would permit consolidation of staff resources into major *Branches* or *Divisions* with allied or integrated problem interests. Further subdivision into *Sections* or *Units* could, of course, be set up as necessary. The scope and complexity of a nation's agriculture would govern the degree of sophistication of the research structure.

Central and State Responsibilities

Where a nation is divided into a number of states or provinces there are differences of opinion about the degree of centralization, and of participation by national governments in agricultural research. Those favoring major responsibilities for the states are concerned about: (1) impediments of bureaucracy or procedural restraints associated with large-scale organization, (2) difficulties posed by highly diverse agricultures, particularly when associated with wide geographic dispersal, and (3) the notion that agriculture and rural development should have a strong "grassroots" orientation for planning and implementation.

It is true that administrative or procedural restraints, when program as well as management decisions are vested in non-technical personnel, represent a major handicap to the freedom and flexibility required by a research organization. Such limitations, however, are not directly a function of size and may be as serious in small, decentralized or dispersed units as in large centralized organizations.

The various disadvantages of centralization are offset by the benefit of the stronger national budget support and more effective use of specialized personnel and equipment through integrated national programs. National governments must be concerned about agricultural improvement as an integral part of of total national development. To divorce national concerns for research from other components of agricultural development blunts one of the key cutting edges in the development process. The value of a positive interest from top national leadership in agriculture, including awareness of the importance of new technology inputs, has been well-demonstrated in the intensive production programs in Asia in the past three years.

Distance or geographic separation should present no particular problem in the outreach of national research. It is no more important when measured from Islamabad to Dacca or from Bogor to Medan than when measured from Beltsville to Brawley. There is ample evidence of initiatives or innovative research supported by the USDA in developing or maintaining the cotton industry, melon production, and other agricultural enterprises in California.

To limit the central government role in research to a generalized function of planning and fund granting is not sound for most developing nations. The U.S. experience demonstrates the value of full participation and involvement in conceptualization and planning as well as in implementation of research by scientists from the various disciplines involved in a coordinated effort. In developing countries such joint participation has proved to be equally important in ensuring follow-through on all aspects of coordinated programs. The limitation of a central council of research or supportive body to the sterile function of granting funds for research projects has no real merit in coun-

tries where the research capability is limited, widely dispersed, and lacks the essential institutional base.

The types of activities which are pertinent for a central or national agricultural research organization were considered by the Joint Pakistan-American Agricultural Research Review Team [Pakistan, 1968]. In its report the team presented recommendations for improvement of the national research structure, including the revision and strengthening of the Pakistan Council of Agricultural Research. It was proposed that the functions and procedures of the Council include the following:

> The Council should serve as the principal technical arm of the Ministry of Agriculture and Works, in strengthening agricultural science and technology in the country and in keeping the Ministry abreast of research developments in Pakistan and abroad.
>
> The Council should have an active, positive role in identifying problems confronting Pakistan agriculture and in planning, with appropriate research organizations of the provinces, the agricultural universities, and other organizations, cooperative and coordinated research projects for the solution of such problems.
>
> The Council should have a cadre of well-qualified scientists who would participate in research schemes, and in case of research of broad regional or national significance, may serve as coordinating leaders of the project.
>
> The Council should work primarily with, and through, the existing research institutes, universities, and other organizations, but should be authorized to establish special research institutes or directorates for particularly important problems or nationwide scope if this becomes necessary.
>
> The Council should have an adequate scientific staff at the director level, to furnish capable leadership in research evaluation, planning and coordination in the major fields of agricultural research and development including (a) crop husbandry, (b) animal husbandry, (c) soils, irrigation and engineering, (d) agricultural economics and statistics, (e) forestry and range management, and (f) fisheries. Supporting staff should be provided to deal with various specific problem areas within each field.

The question of rural or grassroots involvement requires

special attention. The land grant colleges were established in the U.S. to give primary attention to the needs of rural people and the agricultural research and education institutions in the developing nations should have this same major objective. There must, of course, be strong linkages between the central or regional research centers and the local communities in problem identification. But the analysis and solution of a problem usually requires the combined competence of trained scientists from the relevant scientific disciplines. The limited number of agricultural research workers in most developing nations precludes having such multidisciplinary team capability in local stations or centers.

Linkages Between Research, Education and Extension

The sharp focus of this paper on research systems and the thesis that directed research of real impact in fostering growth and development cannot be generated as a by-product from isolated institutions developed primarily for teaching purposes, does not minimize the significance of the teaching function. But it is important to assess the separate functions of research, education and extension and to determine the organizational or institutional structure best suited to furnish the growth-promoting contributions of each.

In the same manner that the organizational base for research should be assessed, provisions for education—including vocational and in-service training as well as higher academic education—should be considered from the standpoint of *national* requirements. The number and type of agricultural education centers will, of course, depend on the manpower needs as well as the ecological diversities in the agricultural regions of the country. While few developing nations might wish to commit themselves to the pattern of an agricultural college for each state or province, as was the case in the U.S. in 1862, at least one agricultural university should be established in all nations with a significant rural population or agricultural sector to furnish effective education for agricultural scientists and extension specialists through the B.S. degree level. And most developing nations will need several such institutions.

Effective functional linkages between research and education

should be considered not only from the standpoint of utilizing trained scientists for teaching, but also to ensure the exposure of all students to the experimental methods of science. This is especially important for advanced students at the M.S. and Ph.D. level.

For the dissemination of improved technology, extension specialists—or subject matter specialists—should be located at the principal research centers. These individuals should be trained at least to the B.S. degree level and preferably should have graduate training and research experience since they will be expected to understand fully the significance of individual technological advances as well as their proper combination into "packages of practices" which are increasingly the pattern in modern agricultural technology. These extension specialists would be responsible for planning adaptation and verification trials, in collaboration with state or local extension workers or others responsible for transmission of new technology and related production inputs to the farm level.

The broader role of "information services" must also be kept in mind, with attention to the communications linkages facilitated by library and documentation centers, publications, etc. The deficiency in such information resources is one of the most significant features of most countries where agriculture is less advanced.

Some Emerging Patterns

While there has been only limited attention to the planning of total "national systems" of agricultural research in most of the developing countries, substantial progress has been made in building some of the key components. And in a few cases steps are being taken to associate these through cooperation or collaboration into nationally institutionalized systems.

The National Research System in India

The steps taken to strengthen agricultural research and college-level education in India, including the development of

all-India crop improvement schemes and agricultural universities, provide a pattern of procedures for building such institutions and for assembling them into a coordinated national system. The review by a joint team of U.S. and Indian agricultural scientists-educators in 1955 [ICAR, 1955] identified the existing capabilities and developed recommendations for strengthening research and college-level education activities. Subsequent joint teams, in 1959 and in 1963, provided continuous assessment as steps were taken to implement the initial recommendations.

In 1955, while the First Joint Indo-American Team was conducting its study on a national basis, two-man teams from the universities of Illinois, Missouri, Tennessee, Ohio State and Kansas State undertook more detailed reviews of possibilities for strengthening the agricultural education programs in various agricultural regions of the country. This led to the USAID/university contracts supporting the establishment of the new agricultural universities.*

The Rockefeller Foundation was invited by the Government of India to follow-up on certain recommendations of the First Indo-American Team, particularly the establishment of a post-graduate school at the Indian Agricultural Research Institute and to develop cooperative research programs for improvement of cereal crop production, with initial emphasis on maize, sorghums and millets From the beginning of the cooperative Rockefeller program, initiated in 1956, special emphasis was placed on strengthening indigenous institutions and on shaping them into coordinated national systems of cooperative research. In contrast with the Foundation's agricultural programs in Mexico, Colombia and Chile where "Offices of Special Studies" were established to provide for a degree of linkage with the ministries of agriculture in those countries—but also to ensure a high degree of autonomy and flexibility—the cooperation in

* A resume of the institution building pattern for agricultural research in India was presented by the writer [Moseman, 1964] and a more recent case study of the role of USAID/U.S. university technical assistance was made by Kathleen M. Propp [1968] of the University of Illinois. A companion report, from the Indian viewpoint, has been prepared by Dr. K. C. Naik [1968], Vice Chancellor of the Mysore University of Agricultural Sciences at Bangalore.

India, from the beginning, was integrated closely with the Indian Agricultural Research Institute and the Indian Council of Agricultural Research.

The regional centers for the cooperative research schemes were located to the maximum extent possible where it was expected that new agricultural universities would be established by the state governments. Support for maize research by the Indian Council of Agricultural Research, formerly fragmented into separate and essentially isolated projects, was consolidated into the "All-India Maize Improvement Scheme." This pattern was followed subsequently for cooperative research on sorghums, millets and wheat, with central government support linked to the agricultural universities and to the ministry of agriculture of each state.

In addition to assistance in the development of the postgraduate school at the IARI, the Foundation furnished substantial guidance in planning the agricultural universities. Dr. Ralph W. Cummings, the field director of the Foundation's agricultural program, served as the chairman of the Government of India committee designated to develop proposed legislation and patterns of organization for the new agricultural universities which are designed along lines of the U.S. land grant institutions.

The establishment of the Postgraduate School at IARI—with its revised curriculum, changed examination systems, modified research and teaching programs, and combinations of major and minor courses—helped to establish this pattern in India's new state agricultural universities. The latter were assisted, under USAID support, by staff from the U.S. land grant universities of Illinois, Missouri, Tennessee, Ohio State, Kansas State and, more recently, Pennsylvania State.

Linking the cooperative crop improvement research programs into the emerging agricultural universities has been most effective in strengthening the experiment station component of these universities, particularly in the states of Uttar Pradesh and the Punjab for which special appropriations were made by the Rockefeller Foundation for equipment and general development of the stations.

The cooperative program in India demonstrates what can be done in a brief period of slightly more than a decade through the deliberate use of adaptive research programs and related agricultural education projects to assemble an effective national system of agricultural research. It demonstrates also the merits of coordinating technical assistance resources from the U.S. government, universities and private foundations.

Emerging Systems in Other Countries

The evolution of a national structure for agricultural research closely linked with educational institutions is perhaps further along in India than in most other developing nations. It therefore supplies a pattern for other countries, especially those with a sizeable and diverse agriculture.

The key elements for similar systems are coming up in a number of other Asian countries. The agricultural universities at Lyallpur in West Pakistan supported by Washington State University, and at Mymensingh in East Pakistan, with cooperation from Texas A&M University, both funded by AID, provide potentially strong educational centers with growing research components. The adaptive research teams in both East and West Pakistan supported by the Ford Foundation for wheat and rice improvement supply pattern-making research projects of regional and/or national scope which could be utilized to build effective collaboration among the several regional research centers and with the agricultural colleges and universities. The Joint Pakistan-American Agricultural Research Review Team of 1968 has recommended steps for strengthening the national research capability through the use of such emerging resources.

The initiatives taken by the Government of Malaysia in setting up the Malaysian Agricultural Research and Development Institute provide an attractive opportunity for developing a national system in a situation where the existing institutional structure is relatively simple. But the evolution of the system faces a number of interesting challenges. Because the number of well-trained agricultural research workers now available is

limited, building an effective national institutional structure will take considerable time. Special attention will be required to establish acceptable relationships between West Malaysia and East Malaysia. In the former, the responsibility for agriculture is vested in the central government, while in the two states of East Malaysia, Sabah and Sarawak, agriculture is a concurrent or joint responsibility. The national development objectives call for expansion of the agricultural base from the present strong emphasis on export crops, primarily rubber but increasingly oil palm, to greater self-sufficiency in rice production and further diversification into other food crops and livestock. This will require modifications in land and water use patterns and will reveal a wide variety of problems to be resolved by more extensive research.

In Latin America, the national research center at Chapingo, Mexico, and the outlying branch stations provide a good national structure with effective linkage to the school of agriculture and graduate school at Chapingo. From a similar evolution from Rockefeller Foundation collaboration, the Institute of Agriculture in Colombia, with national headquarters at Tibaitata and well-located regional research stations, and with linkages to the national university in Bogota, and the faculties of agronomy at Palmyra and Medellin, furnish a national structure of emerging strength. The collaboration of the University of Nebraska under AID support in recent years has added an important element of technical assistance in this effort.

The research-education structure in Peru is evolving, with the collaboration of a number of organizations including a long-term association of North Carolina State University under an AID contract. In Brazil AID has given effective support through several U.S. land grant universities at selected locations. Improved coordination of these activities could furnish a strengthened national agricultural research organization.

In Nigeria, also, the AID-supported contracts with the universities of Wisconsin, Kansas State and Michigan State should result in strong regional education-research centers. A principal deficiency, however, is the absence of a strong nationally-supported agricultural research component.

Coordinating Technical Assistance Resources in Building National Agricultural Research Systems

A major deficiency in most past cooperative efforts has been omission of the ultimate goal of building increasing education and research capabilities into a national, self-sustaining system. The special challenge, and one of increasing urgency, is to associate the technical assistance resources which are currently available to a developing nation, as separate specialized projects, into a coordinated effort to establish such a national research system.

The prime factor in such efforts will be the recognition by the developing nation, as well as by donor cooperators, of the significance of this objective. Collaboration among donors should not be difficult but it would require constant awareness of the need for some modification in present individual support or emphasis to ensure effective meshing of total resources.

Coordination of the individual projects of different technical or economic assistance organizations to strengthen national research capability can be facilitated through joint participation in a basic plan of procedure including the following:

(1) determine the nature and scope of the national system;
(2) establish priorities for research;
(3) determine the location of the principal field research stations and laboratories;
(4) assign technical and administrative management responsibilities—at the central and/or provincial government levels;
(5) develop a long-term (10-year) schedule for the training of research personnel;
(6) set up similar long-range plans for improving research facilities; and
(7) provide for more effective linkages between research workers, nationally and internationally, and between research, education and extension.

Once this framework has been established relevant cooperative projects may be adjusted to make a maximum contribution to the evolution of the total system.

The various national, international or private organizations—including foundations—cooperating in economic development programs follow different policies and procedures in

supporting technical assistance activities. It is, of course, highly desirable for different donor organizations to retain a high degree of flexibility in use of their resources but there are several options for joint participation in development of national research systems, including: (1) core support, on a continuing basis, directly or through the specialized regional or world research centers; (2) support through selected adaptive research projects such as the food crop improvement research of the Ford and Rockefeller foundations and the USAID-supported research; and (3) direct financial support for the specific purpose of strengthening the national institutionalized research systems.

With planned complementarity of support from internal as well as external sources considerable progress can be made in developing national research capabilities by channeling only a small portion of such resources—and attention—to this objective. From the experience in building the U.S. agricultural experiment station system, however, and the experience with technology in the U.S. foreign aid program of the past two decades, it is obvious that the agricultural science capabilities and systems of developing nations will not emerge unless specific and vigorous attention is directed to this objective. Unless such efforts are initiated or strengthened *now* the concerns about world hunger a decade hence may well match or exceed those of 1966. Agricultural research cannot stand still so long as populations multiply at their current rate, and national self-help in science and technology must no longer be neglected as a major component in economic and social development.

Chapter VIII

SUMMARY AND CONCLUSIONS

1. World food deficits which reached a critical stage in 1965-66 were the culmination of a continuing neglect of agriculture, and of agricultural technology, in the developing nations. Serious assessments of the world food supply-population growth trends in 1966 created a general awareness that food shortages, if not actual famines, must be of critical concern for the balance of this century.

2. Special intensive food grain production programs in the developing countries of Asia from 1966 through 1968 brought many of these countries to approximate food grain self-sufficiency, or to the expectation that their domestic requirements could be met within a few more years. The increased output was achieved through a systematic and integrated marshalling of interrelated resources, including lands and water; larger quantities of fertilizers, insecticides and machines; assured favorable market prices; and "improved packages of practices" for wheat and rice production.

3. The outstanding yield performance of the "Mexican wheats" and of the new rice varieties from the International Rice Research Institute, with their broad adaptation and exceptional responsiveness to fertilizers, focussed international attention on the role of new technology in growth and development. Less well understood, however, is the fact that the exceptional productivity breakthroughs for both wheat and rice represent unusual achievements and there is no real certainty of producing yield boosters of similar magnitude in the future.

4. The short-term food grain production campaigns have not ended the food-population crisis. They have merely bought

time, perhaps one decade, in which to shape new strategies for agricultural growth. With world populations continuing to increase at rapid rates the doubling and redoubling of food supplies in many of the developing nations remains a high priority concern.

5. Experience in Asia in the past three years has demonstrated—and reaffirmed—the significance of new technology as a hard core component of agricultural growth. This supplements previous results with research-based programs in Mexico, Taiwan, Japan and the agriculturally-advanced nations of the world. There is justification for *priority in timing* to development of agricultural technology, to ensure early availability of this responsive working tool.

6. Future world food needs and agricultural growth will be increasingly dependent on improved technology since a major portion of the more productive lands and more readily available water resources are already being used. This is particularly true in the more densely populated nations or regions such as India and East Pakistan.

7. Brief spurts of production and short run injections of new technology will fall short in meeting future growth requirements. A sustained flow of new productivity inputs will be required, based on (a) *adaptive research* to fit generally suited innovations to specific environments, (b) *protective research* to forestall or minimize outbreaks of diseases or pests capable of causing widespread losses, and (c) *innovative research* to supply continuously higher yielding materials and practices.

8. Agricultural research must be long-run and continuing. The "Mexican wheats" emerged from more than 20 years of problem-oriented, multidisciplinary research conducted cooperatively by the Mexican Ministry of Agriculture and the Rockefeller Foundation. It drew heavily on experience and materials from well organized wheat improvement research programs of the U.S., Japan and other countries. And, through cooperation of the FAO, the wheat varieties and production practices were tested extensively for several years in the Near and Middle East countries before the intensive production campaigns were initiated in South Asia in 1966.

9. Improved rice varieties and related technology from

IRRI did not have the benefit of extensive testing before widespread application in Asia. Agricultural scientists recognize the calculated risks involved in the extensive use of such materials and anticipate the restraints or limitations which may be encountered in specific localities as the result of inadequate adaptive or protective research and modification of practices.

10. The development and adaptation of new technology to meet future needs must be done increasingly in and by the developing nations. The limited numbers of specialists in the scientific disciplines of plant breeding, pathology, entomology, soil science, etc., in a few international centers cannot be expected to furnish the type and scope of adaptive, protective and innovative research required for large geographical areas.

11. National capabilities for agricultural research must be strengthened and this objective must receive specific directed effort. Review of the evolution of agricultural research capabilities of the U.S., especially the state agricultural experiment stations, furnishes evidence that a research capability or organization adequate to serve a modern agriculture will not emerge as a by-product from other activities such as education or extension. This evidence of need to focus attention and resources on the establishing or strengthening of research capabilities is reinforced by experience from U.S. foreign aid efforts which have given limited attention to building of research capabilities and have contributed little to the development of this essential "self-help" resource over the past 20 years.

12. Agricultural research in the U.S. has evolved over the past century into *a national system of science and technology* which embraces the research of the U.S. Department of Agriculture, state experiment stations and private business firms. This national system provides for a wide range of basic or background investigations, for applied research, and for adaptive and protective research. Closely allied subject matter specialists and extension programs which transmit new materials and knowledge promptly to farmers are an important part of the system.

13. The U.S. system of agricultural research, while seemingly complex, has a basically simple structure. It is essentially a composite of national, regional, and local projects with vary-

ing degrees of participation from USDA, state, and private resources. Although its present highly sophisticated and integrated structure may be followed as a pattern for larger developing nations, the basic organizational structure—with lesser numbers of projects, of field stations or laboratories, and of staff capabilities—also could be suited to a wide variety of more modest national research requirements.

14. National governments must *support and participate in* agricultural research if agricultural growth is to be a strong positive force in national economic and social development. Limiting the national role to parcelling out of grants to short-term and narrowly focussed projects or to "coordination" is usually unproductive.

15. Deficiencies in existing national research capabilities in the developing countries involve multiple factors, many of which may seem minute, but for which there is no single major panacea. The nature and extent of such restraints can be determined only by a thorough-going study of each specific national situation. The evaluation of existing research capabilities, the determination of requirements and goals, and the development of plans of procedure for training, facility improvement, etc., should be done jointly by each developing nation and the prospective technical or economic assistance "donor" organizations. Where political and administrative leadership is not already oriented to or appreciative of science and technology the initiative in stimulating attention to research institution building may have to be provided by external organizations.

16. Steps have been taken in a number of developing nations in the past several years to assess agricultural research capabilities and to strengthen them. The use of joint teams comprised of agricultural scientists-administrators from the different disciplines from the host country and the assistance organizations provides for interchange of views and mutual understandings of specific requirements, restraints, or conditions of the host country. Experience with this type of joint and periodic review and sustained implementation, as started in India in 1955, is supplemented by more recent similar actions in Pakistan and Indonesia. The emerging national research systems in Mexico, Colombia, Chile and Peru also provide experience for guidance

in strengthening such systems in other developing nations.

17. Support for building national agricultural science and technology capabilities is available from a variety of different donor or cooperating sources. The need for additional support from *technical assistance organizations* to strengthen hard-core research capability seems obvious. Less obvious, but equally justifiable, is support to build systems of agricultural research by *economic assistance or banking organizations,* since sound technological backstopping increases the stability, security, and repayment potentials for loans. Also, if agricultural research pays off—and the annual investment of about $460 million by U.S. industry suggests that it does—it should be regarded as being as "investible" as a dam or a highway.

18. Substantial progress could be made in strengthening national agricultural research systems through moderate modification of the numerous individual projects supported by a variety of national, international and private organizations, to ensure positive contributions to the institution building objective. A coordinated effort, with special attention to development of scientific staff resources, and of well-designed, properly located, and adequately equipped laboratories and field stations, could add the essential technological dimensions to the self-help capability of each developing nation. Such dispersed and pluralistic national agricultural research capabilities will be increasingly critical in meeting the food needs of an expanding world population in the years ahead.

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