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INNOVATION AND AGRICULTURAL DEVELOPMENT: SOME ISSUES ON RESEARCH POLICY

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I. INTRODUCTION

Science and technology became, after World War II, a major force behind economic and social change. More than any other element such as natural resources or economic policy, technological innovation determines the capacity to produce, the productivity of resources and the competitiveness in international markets. This last element is of fundamental importance in the case of smaller countries that must develop with relatively open economies and consequently depend upon their competitiveness for their economic survival.

The profound changes that have taken place both in the institutional setting in which technology is produced and diffused into the production system, and the economic transformations brought about by the resulting agricultural modernization, have also brought new situations and new issues in the discussion of research policy.

This paper attempts to discuss some of these issues and their significance for the definition of a research policy.

The paper has three parts in addition to this introduction. The second part presents an overview of recent institutional and technological developments that have taken place in the region. The third section discusses some major issues that emerge from these developments and suggests their main implications in relation ot an effective research policy. Finally, the fourth and last section attempts to draw some general conclusions.

II. AN OVERVIEW OF RECENT DEVELOPMENTS IN LATIN AMERICA AND THE CARIBBEAN COUNTRIES

During the last two decades the Latin American and Caribbean regions have experienced significant changes in agricultural production and institutions. The creation, and in many cases rapid growth, of research institutions were accompanied by an heterogeneous but rapid and significant process of agricultural modernization that changed quite substantially the structure of production and trade.

The intensity of this process, as well as its qualitative characteristics, must be carefully taken into consideration in the definition of an effective research policy. In particular, there are three main elements that I would like to emphasize because of their special importance.

1. The development of research institutions

Two well-defined stages mark the institutional development of agricultural technology generation and transfer in Latin America, particularly in South American countries: the extent of research efforts and the degree and forms of public research institutions. The first stage lasted from the early 19th century, when research was just beginning, until the middle 1950s; during this period research activity was both erratic and unsophisticated.

The first experimental stations aimed at the generation and/or transfer of new technological knowledge were established in the early 1930s and were more clearly defined in the following decade. The situation however, remained unstable due to frequent changes in their administrative affiliation and, hence, in their financing. The universities and agricultural schools, which played an important role in the early part of this century, progressively lost power to the institutes or departments that depended directly on the agricultural ministries. Eventually, research activities were almost entirely centralized in the ministries.

This institutional model was plagued by deficiencies resulting from the ministries' organizational characteristics. The most important deficiencies were: the lack of stable financial support; poor linkage to the problems and priorities of producers; undirected efforts; inadequate communication between researchers, on the one hand, and technical assistance and extension agents, on the other; and finally, the lack of coordination between technology-generating institutions and those that determine agricultural policy for the effective development of the productive process (prices, credits, services and others) (Trigo *et al.*, Chap. 7, Samper, A., 1979).

The second stage started in the mid-fifties when a set of new elements substantially changed the situation: decentralized institutes with autonomous administrations based on the experience in the United States (The Experiment Station System) were created.

The new institutional model was based on two central ideas: a) the realization that the main element in agricultural development was the adoption of technology; and b) the conviction that a wide range of technology, useful to the Latin American producer, was available internationally. Accordingly, the main goal was to ensure the transfer of technology from developed to under-developed countries. To make this possible, infrastructures geared to adaptive research linking receiver countries with research centers

were needed; research offices of the agricultural ministries were not up to the task. This objective had solid financial and technical support from international sources which made possible the building of facilities and the training of research personnel for the new institutes.

From this process emerged: the National Institute of Agricultural Technology (INTA) of Argentina in 1957; the National Institute of Agricultural Research (INIAP) of Ecuador in 1959; the complex made up by the National Council of Agricultural Research and the National Fund for Agricultural Research (CONIA–FONAIAP) in Venezuela between 1959 and 1961; the National Institute of Agriucltural Research (INIA) in Mexico in 1960; the Agricultural Research and Promotion Service (SIPA) in Peru; the Colombian Agricultural Institute (ICA) in 1963; and the Agricultural Research Institute (INIA) in Chile in 1964. All followed the same general model in which the legal administrative nature is a decentralized, autonomous, public entity that carries out research and transfer activities.1/

The institutional model, though decentralized and autonomous, covers a wide range of products, regions and producer types. They also responded to the view that agricultural technology is a public responsibility implying that public institutions must play an important role.

The technological infrastructure's trend toward modernization can also be seen in other situations where no new organisms were created. In Uruguay's Alberto Boerger Agricultural Research Center (CIAAB), though direct affiliation to the Ministry was maintained, profound operational modifications were introduced which affected technology generation and transfer as well as training, when postgraduate study was included in the Center for Temperate Zone Research and Study, created through the sponsorship of the Interamerican Institute of Cooperation in Agriculture (IICA) in the early 1960s.

Brazil's is an atypical situation. The 1960s brought only slight changes but, in 1973, the Brazilian Corporation for Agricultural Research (EMBRAPA) was created. This organism has certain characteristics that differentiate it from the other institutes mentioned, such as that it does not carry out extension, an activity which was assigned to a twin organism, the Brazilian Corporation for Technical Assistance and Rural Extension (EMBRATER). Most important is the explicit acknowledgement of the need for a multi-organizational institutional model, which includes various public sector administrative levels (national and state) as well as the private sector; priorities and objectives are coordinated by EMBRAPA. For this reason EMBRAPA can be considered an extension of the 1960 institutional model, or a new model which modifies the role of the State and the relationship between the public and private sectors.

From 1960 on, there was a vigorous expansion of research and technology transfer activities based on this institutional model and on growing financial support by international and national sources. The expansion process consisted of field work (the creation of new experiment stations and extension agency networks) and the initiation of extensive training programs for the personnel of the institutes, which led to the development of national infrastructures for postgraduate training in Argentina, Brazil, Colombia, Mexico, Peru and Uruguay.

Other exceptions to the organizational model exist in El Salvador, Honduras and Paraguay, and in the English-speaking countries of the Caribbean. In the first three countries, research has remained a relatively centralized activity under the Ministry of Agriculture. A similar situation exists in the Caribbean countries, though their special relationship to Great Britian and the strong ties that some have developed among themselves make for an important difference. Caribbean countries rely on the University of the West Indies and a regional organization (CARDI) which, together, carry out the vast majority of the area's research activities.

2. Technological cycles in agriculture

Technical change in the agricultural sector requires a rather complex process by which knowledge, human behavior and improved inputs merge in a productive way, resulting in an increase in the productivity of natural resources and human labor.

The first two have been to a great extent assumed to be the responsibility of the public sector which, through research organizations and extension activities, has tried to promote technical change. It is probably obvious that in the case of agronomic practices specially adapted to relatively simple agriculture these two elements are the basis for achieving increases in factor productivity. However, as agriculture becomes more sophisticated, a large proportion of the new technological innovations will be embodied in industrial inputs which require a progressively more sophisticated industrial base as well as distribution and financing mechanisms. Thus in market economies where the state in general does not participate directly in the production of goods, technical change progressively depends on the development of the industrial and services sectors.

Recent works1/ suggest that at least in Latin America technical change in agriculture shows innovative cycles where each cycle is characterized by a dominant technology. In addition, the emergence and sequential nature of some of these cycles seem to be partially explained by the development of industrial sectors which follow a certain logic within the process of capital accumulation in the overall economy. This process has special characteristics in each country and consequently the sequence of some of the cycles and their length will not necessarily be always the same. For example in Argentina and Brazil, although a similar pattern can be observed, fertilizers become important at different moments of the modernization process.

1/ Similar institutions were later created in Panama, Bolivia and Guatemala.

1/ Piñeiro, M.; Da Silva, J.G.

In spite of these differences and for the purpose of this paper it is possible to present a description of the general characteristics and sequential order of technical cycles in Latin America.

Figure 1 presents the sequential nature of the cycles and the dominant technology in each one of them. The general timing corresponds, in a general way, to the more developed agriculture in Latin America generally coincident with the temperate regions.

The first stage is characterized by the diffusion of improved agronomic practices, many of them introduced from abroad, while others were developed by local research institutions and the farmers themselves. It is important to note that, because of the disembodied nature of these technologies, it is virtually impossible for those who create and diffuse these technologies to capture the benefits derived from them. Consequently, the public sector was the main source for the development and adaptation of these innovations. The weakness of public research institutions before the sixties probably explains the modest impact of these technologies and consequently the relative stagnation of agriculture production before the sixties.

The second stage is characterized by the diffusion of a number of powerful technologies that share the main characteristics of being of the embodied type. They are mechanization, improved seeds and agrochemicals. The order in which these technologies are incorporated into production depends on a number of factors. Mechanization and fertilization will be strongly affected by factor endowment and relative prices. For this reason they were rapidly adopted only under certain production conditions. On the other hand improved seeds, which require substantial research work for their adaptation to each specific ecological condition, required for their development the existence of a minimum research infrastructure in the country. Finally, the diffusion of pesticides and herbicides was closely associated to the previous diffusion of highly productive varieties and to some extent to the late development of the more specific and effective agrochemicals in the developed world and to the development of a minmum industrial and distribution infrastructure in the developing countries.1/

The dominant element in this sequence of technical change is the growing importance of technologies of the embodied type. Their diffusion will bring, in market economies, the development of the private sector willing and able to capture the benefits obtainable from the production and distribution of these technologies.

Finally, it is also important to note that, as indicated in Figure 1, the more recent scientific discoveries in the general area of biotechnology could suggest the possible emergence of a third technological stage or cycle characterized by the utilization of research techniques that could radically alter the way in which research is done and in the productivity of agricultural technologies. This third cycle will also intensify the need for more sophisticated and complex research.

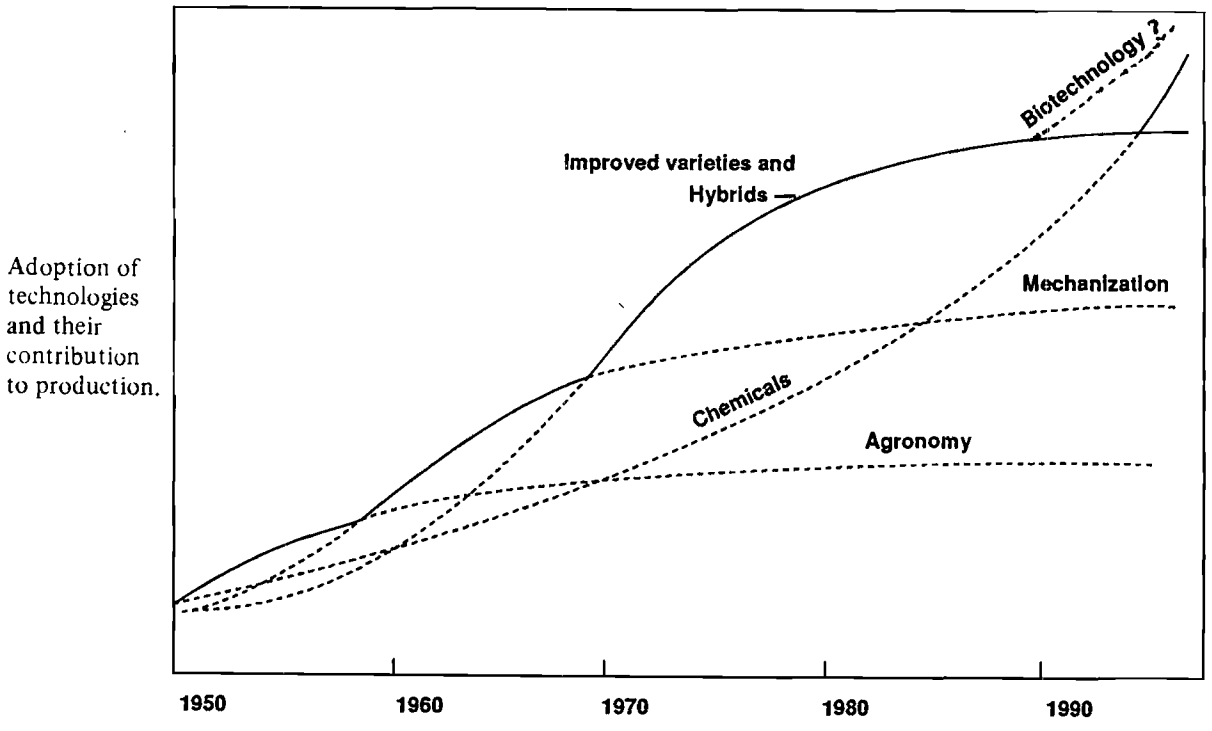

Fig. 1 Technological Cycles

1/ For a more detailed description of cycles see Piñeiro, May 1984.

3. The nature of the modernization

Although the modernization process experienced during the last two decades was significant and had an important effect in total food production and regional trade flows, it was quite uneven between regions, crops and to some extent types of farming.

A major part of modernization was associated either with cereals cultivated in temperate regions under similar ecological conditions to those in the industrialized countries or to tropical crops like sugarcane where international transfer of technology has been strong and effective. A large number of food crops of relatively less importance on a worldwide scale, but important to special regions in Latin America, has not experienced substantive productivity changes.

Modernization has not been exclusively a large farm phenomenon. There are a number of cases where small farms were able to adopt new technology and initiate processes of capital accumulation. However, in general small farming has benefited less from technical changes which had the overall effect of increasing land concentration and vertical integration and a negative impact on income distribution.1/

This is an important theme because technological innovation is a major economic force and our countries must utilize it at its full potential. However, at the same time it is necessary to take additional measures to insure that the costs of modernization are shared in an equitable manner by society as a whole and not by those social groups that have the least capacity to protect themselves.

These actions are mainly related to two things. First, the type of research that receives high priority: which regions, crops and major problems are given the highest research priority determine, to a certain extent, who benefits from them. Secondly development projects, retraining of labor and other similar measures are important policy actions that can be taken to alleviate and socialize the costs associated with agricultural modernization.

III. SOME ISSUES FOR THE EIGHTIES

Agricultural modernization has implied a number of important changes in the general research environment and the emergence of new and important issues in research policy. I would like to present and discuss a few of them that I consider of particular importance. Although the discussion is strongly based on the past experience of some of the larger Latin American countries I have tried, when possible, to make special reference to the specific conditons of the Caribbean region.

1. The growing complexity of technology and the need for basic science

One consequence of the modernization process is the growing importance of basic research as the source of information for creating new technologies. This affects the organization of national research programs.

The national institutes were created with the main purpose of developing technology that has been adapted to the particular conditions of their own countries. This process was to be based on industrialized countries' technology and on basic research available in their public sectors (mainly in the universities). One result of this objective was that the institutes were, at least in the spirit of the law of their creation, restricted as to basic research activities. At the same time, the autonomous nature of the institutes, their affiliation to the ministries of agriculture, and their great size compared to other research institutions, resulted in their developing quite independently from the rest of the national scientific and technical system.

While the institutes were in their growing and expansion stage and their dominant activity was the adaptation of existing technology, this situation did not alter their effectiveness. As technology has become more complex and more dependent on scientific knowledge, the isolation of the national scientific system and its weaknesses have limited the institution's efficiency in its specific task of generating technology.

On the other hand, the growing pre-eminence of complex technologies and their strong dependence on basic science have created conditions for the accelerated development of the private transnational sector; access to technological information in industrialized countries and in certain economies of scale is a basic factor in the ability to compete in the technological input market.

These conditions create new problems for less developed countries. The risk is no longer just the importation of technology that cannot be adapted to their needs. The central problem is the possibility (not immediate but nevertheless real) that, because of commercial practices or international conflicts, a country might not have access to the basic information necessary for developing its own technology. This vulnerability points up the need for a basic science infrastructure that can interact with and replace the international scientific system should the need arise. The infrastructure should be part of the institutes or closely linked to them.

2. New roles for the public sector: the production and distribution of technological inputs

The growing importance of embodied technologies in the innovative process creates the need for the development of an industrial and services sector capable of producing, and/or importing and distributing, the wide array of technological inputs associated with agricultural modernization.

1/ For a discussion of this topic see Piñeiro and Trigo.

It is usually argued that in market economies the private sector will invest in those areas where new needs generate opportunities for private profits. This view is specially congruent with ideas now quite popular in Latin America regarding the existence of an overgrown government bureaucracy and the convenience of relying on the private sector for the provision of all goods and services which are socially needed.

While analyzing this view it is important to review the historical evidence regarding the overwhelming role that the public sector has played in most or all successful cases of economic development in Latin America. The point is that underdevelopment is characterized by a weak private sector, dominated by small business firms with low production technology and limited capacity to enter into high technology production areas. In many cases government is the only organization with sufficient economic and human resources and organizational dimension to be able to start the production and distribution of technological inputs.

For this reason it is likely that in many cases, specially in small countries and/or small markets, a sustained modernization process will require an active role of government organizations in the production and distribution of technological inputs. This role might be temporary and complementary to the activities developed by the private sector, which in the end may become the main or only source for these inputs.

In most cases if the government is to play this role it will be necessary to create new organizations and institutional mechanisms specially adapted for these activities and with special linkages with public research institutions for which they will depend for the provision of the necessary knowledge. It is through these linkages that the whole innovative process will be integrated into one institutional system.

3. Organizational implications for public research

We have argued that as agricultural modernization progresses, and specially as a consequence of the emergence of the private sector as a major source of agricultural technology, the roles of public research institutions must evolve. The general direction of this evolution is to move towards more upstream research activities and more specialized and selective research topics which have a natural complementarity with the applied research emphasized by the private sector.

This likely and desirable evolution of public research has a number of important organizational consequences derived from the fact that different research activities have some very distinct organizational requirements. Some of the more important are discussed below.

Adaptative research characteristic of the early stages of agricultural moderization is dominated by very practical research in agronomy and related fields. This research is best adapted to the work of individual researchers or at best small groups of researchers. It must be highly decentralized and close to real production problems and does not require elaborate and sophisticated programming mechanisms neither to select research priorities nor to organize the allocation of resources. As the focus of research institutions moves to applied research including the development of technologies and products (seeds), the organization of research becomes more complex. Here the concept of multidisciplinary teams organized around well defined projects or programs and with a minimum critical mass becomes of fundamental importance. 1/ Similarly, the selection of competitive research objectives makes it necessary to develop more sophisticated programming mechanisms to allow a rational and orderly allocation of resources.

Upstream research is more removed from the productive system and consequently not always it is possible to relate it to clearly enunciated objectives. It cannot be rigidly planned because results will tend to be less predictable and the very nature of the activity requires a flexible and loose organization that permits the continual redirection of research, adjusting it to results and the intuition and hunches of the researcher. For this same reason research results are more related to the imagination and perception of individual researchers than to the integrated and persistent work of interdisciplinary teams. For this reason upstream research will require an organization that follows more closely disciplinary lines that do not require large and solidly structured teams or departments, but it does require an intellectual environment that provides for permanent and flexible mechanisms for consultation and discussion of ideas and hypotheses with colleagues.

These and other organizational elements will have to be adapted and changed as research institutions move from adaptative research to applied research and finally towards upstream reasearch. Similarly, the structure of newly created organizations should be fine-tuned to the level of development of the country in question and the type of research that the institutions should concentrate on given that level of development.

4. The role of the university and its linkages to research institutions

The institutional model developed in Latin America for agricultural research relied almost exclusively in the creation of national research institutions which, for the most, were not directly involved in teaching. 2/

1/ The concept of large interdisciplinary teams with clearly defined research objectives was initiated with what later was called big science, the best known example being the Manhattan project that resulted in the development of the atomic bomb. Close and well known examples are the crop improvement programs of the international centers of the CGIAR System.

2/ There are a number of exceptions to this general statement. Peru, specially until the early seventies, and Costa Rica are notable examples.

This separation of research and teaching activities was justified on two basic elements: a) the need to have institutions able to respond with agility to the priorities and needs of the development process; the universities, with their academic independence, were seen to follow their own priorities which sometimes respond to a different perception of what is important and necessary; and b) Latin American universities have an excessive level of political activity, which implies uncertainty and discontinuity in research.

Although there is considerable truth in these perceptions, it is also correct that the separation of research from teaching activities has also created a number of problems. First, the absence of students with their natural intellectual curiosity and the stimulating effect of classroom preparation have eliminated one of the main elements of dynamism in research institutions and a major force against institutional obsolescence. Secondly, the lack of integration between research and university teaching made more difficult the development of postgraduate programs as a natural institutional development. I think this is one of the important reasons that explain the notable absence of strong postgraduate teaching in most Latin American universities. Thirdly, the usual organization of universities along disciplinary departments, their traditional independence from political pressures interested in short run problems and the recognition for academic standards usually imply that research in universities has a tendency to move rapidly into basic research. This tendency, which could be considered as a disadvantage at early levels of development, can become a source of strength as the country develops and technological needs become more sophisticated.

It is important to note that the institutional development in the Caribbean region was quite different and that the University of the West Indies is the major research institution in the region. The advantages and weaknesses of this organizational framework under the special conditions of the region should be studied and understood.

5. Critical mass, research teams and the role of regional efforts

We have already mentioned the growing complexity of agricutlural technology and its dependence on relatively complex and sophisticated research. This process has increased the need and importance of interdisciplinary teams of well qualified scientists, and, in some fields, with access to expensive equipment. These requirements imply not only a increasing cost of research activities but also a higher investment in human resources and physical facilities with a longer period of matureness.

As an illustration of the relatively high cost of agricultural research it has been calculated that a well integrated crop improvement program for one of the major species requires an annual expense in the order of US $500,000. It is quite obvious that small countries cannot sustain, economically, a research infrastructure covering the majority of crops and problems needed for a productive and internationally competitive agricultural sector. It is in this perspective that regional research efforts must be seen as an important and probably unavoidable solution for the development of research efforts with sufficient critical mass.

Central America and the Caribbean region, both with a large number of relatively small countries, have made important efforts in the direction of developing regional organizations. It is an important idea and one that offers a viable alternative for productive and economically feasible research activities. For this to happen countries must be willing to provide stable financing and to establish binding coordination mechanisms with their own national research activities in order to pool resources, avoid duplication of efforts and effectively develop a regional network for research and technology diffusion.

6. Linkages to international public research

One of the consequences of the growing importance of basic research is the increasing need for the development of close and effective linkages of national research programs with public research institutions in the developed world. These linkages are necessary in order to have access to scientific knowledge that developing countries cannot produce in all the fields that are needed and important for the development of agricultural technology.

The establishment of these linkages implies the existence in the national programs of at least small groups, sufficiently advanced and specialized, to be able to have effective professional relationships with their scientific counterparts in the developed world. They must be capable of formulating the appropriate questions and of using the answers related to available scientific information in the resolution of problems of applied research. In this function, regional organizations can play an important role both because of their size and the resulting economies of scale, and because of the mobility and flexibility that these organizations enjoy in relation to international travel and access to information.

7. Research priorities and their linkage to production needs

We have argued that universities and regional research organizations are extremely valuable parts of an overall research system, specially as technologies become more complex and more dependent on basic research. On the other hand, both types of organizations are prone to aggravate a basic problem of most research institutions: the selection of research priorities closely related to the solution of production problems in the real world.

This problem is related to a number of organizational and functional characteristics of research institutions. First, it is related to the existence of a well structured and methodologically sound system of diagnosis of production problems and the determination of their relative importance as a basis for assigning research priorities. Secondly, it is also related to the governance of the organization. Technically sound research priorities will be implemented only if the decision making process has the adequate participation of the potential users of the technology and of researchers themselves.

These two elements related to technical and political considerations are more easily met by national research organizations than by universities, which have a higher degree of academic autonomy, or by regional organizations more removed from the farmers or producers level. However, this does not imply that these organizations cannot develop the appropriate organizational and management mechanisms to ensure the necessary linkages between research priorities and real production problems. Each institution must find its own way to ensure these conditions in an appropriate manner, but there are a number of general principles that inform on the alternative solutions to this problem.

8. Technological cycles and the concept of appropriate technology

The discussion of previous sections points to the evolution of agricultural modernization towards more sophisticated and complex innovations of the embodied type. This pattern of agricultural development is closely identified with the experience of the more developed and commercialized agriculture found in temperate Latin America and some regions of the continent.

In many other regions small farming, associated in some cases with a peasant type economic structure, is still important both numerically and in terms of its contribution to total food production. It is obvious that in those countries where this type of production is still important public research institutions must dedicate a substantial part of their research effort to develop technologies appropriate for these conditions, which are characterized by being very site specific, having low capital use and high concentration of labor, and usually associated with small size farms.

Under these conditions agronomic research of the most pure type is still the most important element that may lead to agricultural modernization. It is in this line of thought that the concept of appropriate technology has a new and positive meaning. Following the ideas of one of its main originators (Suchumaker), appropriate technology is usually associated with small size and opposed to modernizing technology. But if one recognizes the evolutionary perspective implied by the existence of interrelated technological cycles which are determined not only by technical elements but also by the level of development of agriculture and the general economy, then the concept of appropriate technology may be redefined to mean that a technology is appropriate if it is congruent with the level of development achieved in each particular case. The argument can be illustrated by saying that hybrid seeds are not appropriate until the country has a research and seed multiplication capacity for the production and distribution of seeds or that sophisticated farm machinery cannot be effectively utilized if a distribution and services infrastructure has not been developed previously.

It is important to note that public research institutions, that must dedicate a substantial part of their effort to the development of agronomic technologies in the early phases of the technological cycle, will also need some specific organizational characteristics. The main point here is the capacity to work under multicrop rotations with strict restrictions in relation to capital and labor availability. Under these conditions the capacity to identify the real production constraints and the interactive relationships between different crops and farming practices is of particular importance. Consequently the organizational structure will have to give particular attention to interdisciplinary teams with regional responsibilities and relatively less attention to either more specialized crop improvement programs or disciplinary departments.

IV. CONCLUDING COMMENTS

In the last few years technological change in agricultural production has rapidly increased, becoming a major element in the modernization of agriculture in a number of countries of the world. These processes were made possible by dramatic changes in the availability of technological innovations in a number of crops of great importance, specially for the temperate regions of the world. In Latin America and the Caribbean region modernization, although important, has been uneven and concentrated in a few crops and regions. The challenge of the decade is to extend this process to a wider range of crops and ecological regions.

The modernization process also implies important changes in the research environment, raising important new issues, problems and challenges. Probably the most important one refers to the organization of public research institutions (including the universities), which have been -and still are- the main source of scientific and technological know-how. How they adapt to the circumstances, define new roles for themselves and organize to remain productive and flexible will be a major determinant of viable agricultural production in the region.

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