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Preface

Donald Winkelmann,* Workshop Coordinator

The following papers were the center pieces of a two-day workshop sponsored by CIMMYT, supported by the Inter-American Development Bank (IDB), and held at CIMMYT headquarters in Mexico on September 10-11, 1984. The workshop grew out of discussions between IDB and CIMMYT relating to the framework within which agricultural research is organized in Latin America and the Caribbean. With IDB concerned about the role of such research in economic development and CIMMYT and its sister institutes CIAT and CIP concerned with supporting the efforts of the region's national programs, there was a clear harmony of interests in the issues orienting the workshop.

IDB's concern with agriculture and its sense of the potential of agricultural research is ever more in evidence in its growing investment in national research programs. Moreover, IDB had completed ten years of support to the three international research centers of the region—CIAT, CIMMYT, and CIP—and other years of support to such regional centers as IICA, CATIE, and CARDI. This congruence suggested that it was appropriate to review aspects of the current situation and, more importantly, to establish a common conceptual framework against which to judge the evolving national, regional, and international effort. Such a framework could guide the collaboration among the various levels of undertaking and assist in assessing the viability and desirability of potential investments in the system over the remainder of the century.

The workshop was organized against this background. Its active participants were the directors of research from the 26 countries of the region along with representatives of the three regional institutions that carry out agricultural research (IICA, CATIE, and CARDI) and of the three international centers based in the region (CIAT, CIMMYT, and CIP).

The six major papers which follow were designed to establish a common framework for discussions about themes important to the region's agricultural research institutions.

The paper by Drs. Alberto Valdés and Eugenia Muchnik projects demands and supplies of important agricultural products to the year 2000. Their work incorporates the probable effects of growing incomes and urbanization on the patterns of consumption. It also considers new technologies. These projections can assist in decisions on the relative importance of various lines of research.

The paper by Drs. Martin Piñeiro and Eduardo Trigo reports on the current state of research institutions, especially publicly supported institutions, in the region. Special attention was given to human and physical capital.

The paper by Dr. Eduardo Venezian concentrates on the current conventions in the organization of agricultural research. These structures feature commodity teams and those organized around disciplines. Emphasis is given to the contributions of the past and to what might be expected of research organized in this way in the future.

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Drs. Edgardo Moscardi and Juan Carlos Martinez examine the newly emerging on-farm research and how it is integrated with the more conventional experiment station research and the extension system. While emphasizing the characteristics of such work and relationships in the present, they also point out how such connections may be strengthened in the future.

The paper by Dr. Willy Roca aims at assessing the potential contribution of biotechnology to the national programs of the region over the next fifteen years. The idea is to establish what such approaches can offer today, what they may offer in the future, and how the three levels of institutions can cooperate to ensure that the countries of the region are able to take advantage of gains being made.

The paper by Dr. Eduardo Casas focuses on the professional staff that is available to the national programs. He goes on to describe the kinds of professional training needed in the future and to point to potential sources of such training.

The papers served as background material for extended discussion on each of the themes. The observations of commentators are included at appropriate places in the text.

One of the great advantages of the workshop was the presence of three Nobel Laureates who have had strong associations with agricultural research in the region. Drs. Borlaug, McClintock, and Schultz commented on selected papers and played important roles in discussions surrounding the major themes.

We believe that the workshop achieved the goals initially established. The discussion, motivated by the papers and comments which follow, has helped to provide a common framework for future discussions about the orientation of agricultural research in the region, about the directions and forms which seem most promising, about crops and commodities to be emphasized, and about sources of collaboration among national, regional, and international programs.

Structure and Tendencies in Production, Consumption and Export Trade of Agricultural Products in Latin America

Alberto Valdés* and Eugenia Muchnik de R.**

Introduction

This paper presents an overview of trends in consumption, production, and trade of agricultural products in Latin America over the last two decades. It seeks to identify and analyze diverse problems in a food security strategy for the region and cites production and consumption projections for the year 2000.

The first section emphasizes the evolution of consumption patterns in Latin America and introduces a hypothesis on the causes and effects of changes in dietary habits. A later section examines the changes in productivity and in the composition of agricultural production within the context of long-term growth. It also reviews the structure and tendency of export and import trade in relation to export potential and food security. The last section deals with projections of food consumption, production, and imports for the year 2000.

Structure and Trends in Food Consumption in Latin America, 1960/1980

Developments in Food Consumption and Malnutrition

In the last 20 years, food consumption Latin America has grown at an annual rate of 2.8%, that is, at a rate similar to its population growth rate.[1] During the same period, total animal feed use of grain grew at a rate close to 5.4% due to the rapid increase in the consumption of meat and dairy products. As will be shown later, total livestock production during the 1970s rose 3.6% annually, a rate higher than that of food consumption. A breakdown into subregions of the increase in human food consumption and in animal feed use of grain is shown in Table 1.

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1 The definition of food used here includes cereals, vegetables, roots, tubers, plaintains and bananas; noncereals were converted to their equivalent in wheat according to the basic caloric content. This estimate takes into account the consumption of livestock and poultry products, fruits and vegetables. Consumption is determined as production-plus-imports-less-exports.

Since it is risky to speculate on the meaning of aggregated figures such as these in terms of nutrition, we identify only general trends here. Some writers maintain that the nutritional state of the lowest income groups in Latin America has worsened (Caballero and Maletta, FAO, 1983). Others such as Reutlinger and Selowsky (1976) and Lynam (1981) estimate the extent of malnutrition by comparing calorie requirements and supply at a certain point in time. This is a critical subject of inquiry; to examine it, we will look into direct and indirect evidence of how the nutrition situation has evolved.

Table 1. Annual growth rate of food consumption 1961/1965 to 1973/1977

	Food[a] %	Grain for animal feed %
Latin America	2.8	5.4
Mexico and Central America	3.3	9.2
Tropical South America	2.7	4.3
Southern Cone[b]	1.4	5.2

Source: L. Paulino (IFPRI) in A. Valdés, 1983

[a] Food as defined in footnote 1
[b] Argentina, Chile, and Uruguay

In the first place, at an aggregated level, the average calorie intake in Latin America has risen moderately over the last 20 years. Between 1961/1965 and 1979/1981, it increased from 2,432 to 2,591 calories per capita a day, while calories originating from animal sources increased from 403 to 455 calories per capita a day (Table 2). The rate of protein intake in the region has been quite stable, and the average protein supply per capita has been greater than the minimum recommended level in each of the countries in the region.[2] The regional average (around 65 grams a day) is close to the world average, although considerably less than that of developed nations.[3]

These averages do not necessarily indicate that the lowest income groups have maintained their portion of the total consumption. One might deduce that the number of people with nutritional problems has increased to the degree that the present income distribution is less balanced than before. Nevertheless, available information on shifts in income distribution does not furnish a definitive answer to this question. As an illustration, it is useful to cite three recent studies which rigorously and quantitatively examine some indicators of the nutritional state.

Mohan, Wagner and Garcia (1981) present estimates of malnutrition in two Colombian cities for 1973 and 1978. On the basis of questionnaires made up by

2 See Seré, 1983.

3 Seré has classified countries of the region in three levels according to their protein intake: Group 1 (≥80 g/person/day) includes Argentina, Paraguay and Uruguay, countries with comparable advantages in cattle production; Group 2 (≤80g and >60g) includes Brazil, Chile, Cuba, Guyana, Jamaica, Mexico, Nicaragua, Trinidad Tobago and Venezuela, and Group 3 (≤60g) includes Bolivia, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Panama and Peru.

Table 2. Patterns of calorie and protein intake in Latin America, 1961/1965 and 1979/1981

Diet components	Calories 1961/1965 (cal/capita/day)	Calories 1979/1981 (cal/capita/day)	Proteins 1961/1965 (g/capita/day)	Proteins 1979/1981 (g/capita/day)
Total	2,432	2,591	64.0	66.3
Vegetable	2,030	2,136	39.7	38.6
Animal	403	455	24.3	27.7
Wheat	306	390	9.5	10.9
Rice	219	241	4.3	4.7
Maize	376	378	9.4	9.3
Other cereals	9	39[a]	0.2	0.8[b]
Roots and tubers	181	147	2.4	2.6
Sugar	386	446	0.1	0.1
Dry legumes	136	103	8.6	6.4
Nuts	26	14	1.1	0.4
Vegetables	23	25	1.0	1.1
Fruits	109	116	1.4	1.4
Meats	197	213	14.3	15.4
Eggs	13	20	1.0	1.5
Fish	11	16	1.8	2.4
Dairy products	127	144	7.2	8.3
Oils and fats			0.1	0.1
Vegetable	127	163	[a]	[a]
Animal	55	61	[a]	0.1
Stimulants	9	6	1.0	0.7
Spices	1	2	[a]	0.1
Alcoholic beverages	65	65	0.1	0.2

Source: Caballero and Maletta, 1983; data for 1961/1965 were taken from a FAO publication, Food balance sheets (1975/1977 average) and per capita food supplies (1961/1965 average and 1967 to 1977), Rome, 1980; data for 1979/1981 are unedited, provisional FAO tabulations

[a] This figure is not exactly comparable to the one for 1961/1965; if the same coverage were used, it would probably be lower

[b] Not significant (less than 0.05 g)

WHO/FAO and the Colombian Institute for Family Welfare (ICBF), they concluded that in 1978 the ratio of population with a food intake below the required level had declined compared to 1973. In 1973 in Bogota, the ratio was between 29 to 35% (30 to 40% in Cali), and in 1978 it went down to 10 to 16% both in Bogota and in Cali.

Miguel Urrutia looks at the evolution of family income and expenditures of the lowest income groups in the Cali region in 1970, 1974, 1976 and 1980 (Urrutia, 1981). He found that real family income of these groups in Cali increased substantially between 1970 and 1980, and that the portion of the budget spent on food declined from 79% in 1970 to 51% in 1980; this fact is very important from the point of view of food consumption. Between 1970 and 1974, total per capita expenditures for food (in deflated, absolute terms) was slightly reduced, and then increased substantially during the second half of the decade. At the same time, Urrutia found that real wages of the lowest income groups in Cali (farm workers and noncontract women workers) rose more rapidly than the national income per capita in the 1970s.

Finally, a study by Castañeda in Chile detected a constant and dramatic decline in that country's infant mortality between 1955 and 1983. Mortality for infants less than a year old went down from 116.5 per 1,000 live births in 1955 to 21.0 in 1983 (Castañeda, 1984), in spite of the increase in urban unemployment in 1975/1976 and 1982/1983.

It is difficult to reconcile these findings in Colombia and Chile with the opinion that the nutritional state of the lowest income groups in these countries has worsened. Simply trying to measure the deficit in the supply of calories at a certain point in time can be misleading in middle-income countries, as are most Latin American nations. Recent analyses, such as Srinivasan (1983) and Poleman (1983) have made, are devastatingly critical of available data on the nutrition gap which are based on aggregated calorie supply and requirements. We learn much more about the extent of malnutrition by examining trends in food consumption and expenditures as well as by the judicious use of direct indicators of the nutritional state.

The fact that malnutrition seems to be diminishing in this region does not imply that it has disappeared. No doubt malnutrition exists; to what extent is contingent not only on food prices, but also on the purchasing power of the poorest families, many of which live in the urban area. Agricultural development contributes to solving this problem, especially if it raises the income of small farmers and rural wage earners and lowers relative food prices. But perhaps the real solution depends more on how dynamic total economic growth is.

Changes in Food Consumption Patterns

Besides the changes in total calorie and protein consumption that have been pointed out, there are significant modifications in the composition of the Latin American diet, which is gradually coming closer to the food patterns of more developed nations. The following modifications appear in Table 2 (which goes with Table 3):

- There has been an increase in wheat and rice consumption per capita, but consumption of maize and other indigenous cereals typical of the traditional regional diet has declined significantly (Table 3). Cereals as a whole continue to account for approximately 40% of total calories.
- Consumption per capita of vegetable oils has accelerated greatly and consumption of vegetables and fruit has gone up somewhat.

- Consumption per capita of roots and tubers (cassava, potatoes) and dry legumes (beans), typical staples of the traditional Latin American diet, has decreased greatly, as can be seen in Tables 2 and 3, and Table 1 in the Appendix.

- There has been an increase in per capita consumption of meats (especially poultry), eggs and dairy products. This caused an increase in use of forage grains such as maize.

The fact that diet has recently diversified to include a more ample variety of staples containing high amounts of protein and other nutritious elements confirms that exclusive use of the calorie intake along with a restricted roster of products (excluding livestock products, fruits, and vegetables) is not appropriate in assessing the trends in food consumption. This has even proved to be true from a nutrition point of view in middle income countries, as are the majority in this region.

Explaining Changes in Consumption Patterns

We can suggest various hypotheses to explain the changes in the diet of the average Latin American consumer. First of all, the pronounced rural-urban migration in most Latin American countries has brought about changes in dietary habits.[4] Urbanization favors the consumption of more storable processed foods with a lower cost of preparation (i.e., wheat derivatives, rice, and vegetables), but not of typical foods such as cassava, potatoes, quinoa (in Andean countries), and dry legumes. Women's growing participation in formal labor markets suggests that food preparation time in the home is very important. These urban consumption patterns are spreading to rural areas as the number of wage earners who must buy a large portion of their food increases, although the rural population continues to follow more traditional consumption patterns.

Secondly, it is to be expected that as the average income rises, the consumption of foods (and their raw materials) with high income elasticity of demand will proportionately increase. Since most of the demand comes from middle and high-income groups, the supply of products they demand will expand. Conversely, low-income elasticity products will go down in relative importance, especially among middle and high-income strata.

Next we will mention different estimates of income elasticity of demand by income levels and by urban and rural areas in Brazil, Chile, Colombia, and Peru. Unfortunately, in a simple analysis such as this, the urbanization effect is not differentiated from the effect of income growth, though they tend to occur simultaneously.

Table 4 displays income elasticity of demand for several staples at each income level in Brazil, the parameters having been differentiated according to urban or rural consumers. Williamson (1982) obtained these estimates from a Survey of Family Expenses and Anthropometrics carried out by the Brazilian Institute of Geography and Statistics (IBGE) in 1977 and 1978. Products with higher income elasticities have increased their participation in the diet (meats, dairy products, vegetables, fruits, oils, and, among the cereals, bread). Consumption of traditional foods such as roots (cassava), maize, and legumes, which have income elasticities that are negative or not

4 Table 2 in the Appendix lists the growth rates for rural and urban populations in Latin America in 1950/1960, 1960/1970 and 1970/1976. During this last period, rural population grew at annual rate of 0.91%, while urban population rose 3.71% annually.

Table 3. Latin America: main diet components during 1964/1966 and 1975/1977 (kilos per capita per year)

Regions and countries	Wheat[a]		Rice[b]		Maize		Potatoes		Fresh cassava[c]		Dry beans		Beef		Pork		Poultry	
	1964/ 1966	1975/ 1977	1964/ 1966	1975/ 1977	1964/ 1966	1975/ 1977	1964/ 1966	1975/ 1977	1964/ 1966	1975/ 1977	1964/ 1966	1975/ 1977	1964/ 1966	1975/ 1977	1964/ 1966	1975/ 1977	1964/ 1966	1975/ 1977
Mexico, Central America, and the Caribbean																		
Mexico	20.7	29.9	4.1	5.3	113.8[d]	99.3[e]	6.3	9.2	- -	- -	17.9	12.7	8.8	9.5	7.4	7.2	2.0	4.6
Cuba	68.1	55.3	40.3	48.3	- -	- -	15.3	13.3	21.8	17.1	2.9	2.2	26.6	16.7	6.1	5.9	3.8	8.1
Dominican Republic	13.2	19.1	31.5	41.4	7.0[d]	5.8	4.2	3.3	27.4	25.9	9.7	6.8	8.9	7.6	3.0	3.6	3.7	6.9
Costa Rica	30.2	27.7	30.5	38.7	54.9[f]	19.7	12.7	9.4	6.2	4.7	10.8	10.5	20.8	18.8	3.5	3.3	1.7	1.6
El Salvador	10.6	13.3	5.8	6.6	125.9[f]	77.0	1.9	6.0	3.0	3.1	10.2	9.3	8.0	5.9	3.1	2.7	1.5	2.2
Guatemala	13.9	15.3	2.0	3.2	196.2[f]	97.7[e]	1.5	3.4	1.1	0.7	10.5	9.9	9.6	8.5	2.7	1.4	3.8	2.3
Honduras	9.5	11.5	4.1	5.9	160.8[f]	94.1	2.0	1.2	11.1	2.7	12.9	7.6	7.0	7.3	5.6	1.7	1.6	3.3
Nicaragua	12.8	14.9	19.7	15.0	138.1[f]	69.5[e]	1.2	3.0	7.6	8.7	21.7	19.0	15.2	22.2	4.3	4.9	1.0	2.9
Panama	23.0	20.9	61.0	62.0	33.3	20.2	6.4	5.6	11.1	16.4	6.0	2.7	19.4	28.5	2.3	3.6	3.8	5.7
The Caribbean																		
Haiti	96.0	14.4	5.5	18.6	47.3[d]	31.4[e]	0.2	1.3	23.2	22.1	8.9	9.0	3.2	4.2	3.2	5.5	0.5	0.9
Jamaica	56.0	58.5	16.6	20.6	12.7[d]	8.6[d]	7.3	4.4	3.5	8.9	- -	- -	9.3	11.6	3.0	4.0	4.5	18.9
Trinidad Tobago	64.5	73.2	35.9	41.6	- -	1.6[e]	11.3	11.4	- -	4.1	- -	- -	4.8	6.7	5.5	3.5	11.0	20.4
Tropical South America																		
Bolivia	32.2	38.1	6.0	15.0	44.8[f]	24.8	103.4	104.3	24.7	38.7	0.2	0.4	9.2	16.3	3.1	5.5	0.6	1.0
Brazil	21.1	30.2	46.4	39.3	19.2	19.0	9.8	10.8	90.6[c]	74.4	24.0	17.0	18.2	19.5	8.2	7.5	2.6	5.3
Colombia	12.2	12.5	21.8	29.6	46.2	27.4	31.4	42.8	25.3	39.7	1.2	21	23.9	23.9	3.3	4.1	2.1	2.9
Ecuador	14.7	24.8	16.1	21.2	22.3	20.2[e]	52.4	59.0	14.1	22.1	4.8	3.5	11.0	11.6	6.4	4.0	1.6	2.4
Paraguay	29.1	17.9	5.4	13.4	45.3[d]	55.2[e]	3.0	1.2	180.8	160.8	9.4	20.2	42.3	36.2	15.8	22.2	3.0	3.8
Peru	36.6	40.6	24.5	26.1	20.7[d]	21.9[e]	84.7	75.8	29.6	22.2	3.1	3.6	10.0	6.7	4.2	3.7	2.6	8.0
Venezuela	43.1	32.7	9.0	13.1	34.3[d]	37.6	11.6	11.1	23.3	16.6	6.3	5.3	22.5	25.4	6.3	5.5	6.6	14.0
Southern Cone																		
Argentina	96.1	91.0	4.0	4.3	- -	4.5[e]	67.8	53.7	2.4	4.0	0.7	0.9	82.5	93.8	7.7	10.2	1.5	8.7
Chile	118.9	121.7	8.1	7.8	2.1[c]	- -	66.4	43.7	- -	- -	4.8	4.2	18.2	23.0	5.9	3.2	2.1	4.2
Uruguay	86.3	78.7	8.5	8.2	- -	9.4[e]	37.2	31.1	- -	0.7	1.1	0.7	90.2	81.1	9.0	5.6	2.2	5.3

Source: CIAT, 1983, based on FAO, 1971 and 1980

[a] Wheat flour [b] Rice paddy [c] Includes bitter cassava [d] Maize food [e] Maize flour [f] Maize cakes

different from 0, has diminished. In addition, Table 4 indicates that the elasticities of staples decline as income rises (in keeping with Engel's Law), a tendency that is succinctly revealed through the income elasticities of demand for calories at each income level. This parameter also shows, for each income level, that elasticity is greater in the rural area than in the urban sector.

Consumer preferences revealed in income elasticities of demand are similar in the rural sector, even at the lowest income level: roots and legumes have negative elasticities and, of the cereals, maize has rather high elasticity though it is lower than that of rice or bread.

Table 4. Income elasticities of the calorie intake for basic products selected by income levels, Brazil, 1974/1975

Product	30%/o lower		50%/o level		20%/o higher	
	Urban	Rural	Urban	Rural	Urban	Rural
Cereals	0.65	1.0	0.19	0.25[a]	−0.07	0.12
Rice	0.85	1.99	0.30	0.17[a]	−0.22	0.17
Maize	0.33[b]	1.18	−0.15[b]	−0.04	−0.04[b]	0.09[a]
Bread	1.09	1.47	0.12[b]	0.32[a]	0.14	0.13[a]
Roots						
Cassava flour	−2.09	−3.50	−1.30	−1.59[a]	0.33[b]	−0.36[a]
Sugar	0.65	1.25	0.25	0.24[a]	−0.03[b]	0.08[a]
Legumes	−0.20[b]	−0.34[a]	−0.11[b]	−0.36	−0.18	0.08
Vegetables	1.27	1.52[a]	0.78	0.35	0.10	0.27[a]
Fruits	−0.03	0.38[a]	0.58	0.64[a]	0.40	0.08
Meats and fish	0.41	0.36[b]	0.34	0.48[a]	0.24	0.08
Beef	1.45	1.22[a]	0.74	0.68[a]	0.15	0.15[a]
Dairy products	0.81	1.52	0.72	0.63[a]	0.37	0.06
Milk	0.73[b]	2.27	0.95	0.15	0.06[b]	−0.17[a]
Eggs	1.15	1.93	0.60	0.63[a]	0.10	0.11[a]
Oils and fats	1.56	2.53	0.87	0.65[a]	−0.04[b]	−0.32[a]
Total calories	0.28	0.47	0.18	0.20[a]	0.04	0.06[a]
Average calories per capita	1,713	1,963	2,008	2,432	2,293	2,771

Source: Williamson, IFPRI, 1982. Based on information provided by IBGE, National Studies on Family Distribution of Income; Food Consumption, Anthropometric, Rio de Janeiro, 1977/1978

[a] Not significantly different from the urban estimate ($a = 0.05$, two-tailed test)
[b] Not significantly different from zero ($a = 0.05$)

Comparable estimates for Peru (Amat y León, 1981) (Table 3, Appendix) indicate that:

(a) elasticities in the rural area are higher than in Greater Lima;[5]
(b) food groups with the highest income elasticities in Lima and rural areas are beverages, dairy products, fruits, eggs, and meats, and
(c) cereals and legumes, as well as roots and tubers, have relatively low elasticities in urban and rural areas.

Table 4 in the Appendix displays average income elasticities for each staple in Santiago, Chile, according to a survey of family budgets for 1977 and 1978; here the highest income elasticities correspond to beef, dairy products, fruits, eggs, and vegetables, in that order. In comparison, cereals, potatoes, beans, and sugar have very low elasticities. Table 5 in the Appendix shows that in Colombia products with the highest income elasticities are meats (pork and poultry), peas, rice, fruits, bread, and dairy products, in that order; those with the lowest are potatoes, beans, plantains, and cassava. These elasticities decrease the higher the income level, a tendency especially marked in beans, eggs, cassava, fats, and plantains.

An additional factor that has affected consumer patterns, besides the urbanization process and economic growth, is the modification of relative prices as a result of technological changes and/or price policies implemented in the region. An example of the impact of technological change is the large increase in poultry consumption in various Latin American countries. It has been suggested that this could be the consequence of the fall in poultry prices due to the adoption of modern technology that reduced the production costs per unit and improved marketability. An additional example is in Colombia and other countries where the spread of modern varieties of rice increased the supply of this staple substantially and reduced its real price.

With regard to price policy, one of the permanent concerns of economic authorities in Latin America is keeping the food supply at stable and, sometimes, low prices. Because of the importance of certain staples in the consumer basket, reflected in the Consumer Price Indices (CPI), especially in middle and low-income urban areas, controlling these prices is a convenient way of regulating wage pressures and the cost of living.[6] There is a variety of mechanisms used to control these prices (i.e., direct price controls, differential tariffs, export tariffs, and over-evaluation of local currencies).

The most dominant group in the CPI is meats and meat derivatives, followed by cereals and cereal derivatives. In individual products, wheat and wheat derivatives fluctuate between 3.2 and 7% of the total index (Table 6 in the Appendix), with rice and maize lower. Beef goes from 3.2% (Peru) to 15% (Paraguay), and is above 6% in other countries. Milk ranks after wheat and beef (Table 6 in the Appendix), but beans, cassava, and pork have less weight in the CPI. Greater concern in controlling prices of high volume goods is understandable, though this frequently brings about a lack of incentives for their local production.

5 The higher income elasticity in the rural areas is derived from the lower average income of rural families.

6 Table 6 in the Appendix illustrates the significance of different staples in the family budget, calculated by their participation in the average total expenses of urban families in various cities of the region. It is to be expected that there will be price controls on the most important products, such as beef in Argentina, Brazil, etc.

Besides specific price controls, subsidy policies and implicit taxes on production and consumption are common. Calegar and Schuh (1984) studied wheat policy and its effects in Brazil during 1965/1982. Whereas wheat production policy was designed to discourage imports, the policy of subsidizing consumer prices stimulated wheat consumption to such a degree that more wheat imports were required. Starting in 1973, the annual nominal rate of consumer price subsidies was no less than 38%, and in 1980 it reached 84%. That same year, annual wheat consumption was 37% greater than had been projected without consumer subsidies.

Trends in Food and Agricultural Production, 1960/1980

Food Production

Between 1961 and the middle of the 1970s, food production in Latin America grew at an annual rate of 3.2%, that is, 0.5% faster than its population growth.[7] Latin America had the fastest growing food production of all the developing world, since in the same period Asia's growth rate was 2.6%, North Africa's and the Middle East's were 2.5%, and Sub-Saharan Africa's was only 1.5%. Among Latin American subregions, Mexico, Central America, and the Caribbean had the highest growth rate in food production, followed closely by Tropical South America. The Southern Cone showed the lowest growth, but in all three subregions, food production rose at a faster pace than the population.

The situation changed radically in the second half of the 1970s; during this time, food production in the Third World accelerated, while in Latin America it diminished sharply from 4.2% annually for 1961/1970 to only 1.7% in 1971/1980. This was true for all three subregions (Table 5) (Valdés, 1983); to some extent, the decline could be the result of the fall in the real rate of exchange over the last decade after the massive influx of foreign credit to the region.

The main difference between the source of the food production increase in the 1960s and the 1970s was in the expansion in cultivated area. During the 1960s, it expanded at an annual rate of 2.7%, while yields increased 1.5%. In the 1970s, the increase in cultivated areas diminished to 0.6%, and the rise in yields went down slightly to around 1% annually (Table 6). Thus the contribution of expanded cultivated land to the rise in food production decreased from 65% in 1960 to 37% in the 1970s. Table 6 shows that the relative contribution of expanded farm area and yield increases varies with each subregion. Mexico, Central America, and the Caribbean maintained a high rate of yield increases (over 2%), and for the Southern Cone yield increases went from 0.9% in the 1960s to 2% in the 1970s. Tropical and Sub-Tropical South America's growth in yields went from 0.8% in the 1960s to 0 in the 1970s; the expansion of cultivated land diminished drastically from 3.7% to 1.8% annually. To sum it up, temperate and sub-tropical zones in Latin America have increased their yield per hectare, while Tropical Latin America has not.

Products listed in this food production index include coarse grains and tubers only; possible increases in the production of other agricultural products such as livestock, fruits, oil seeds, cotton, sugar, etc., are therefore not shown. Oil seeds, for example, has expanded rapidly in the last decade.

7 Staples are cereals, vegetables, roots and tubers, plaintains and bananas, as in the last section. Noncereals were converted to their equivalent in wheat according to caloric content.

Table 5. Rate of annual growth in production, harvested area, and yield per hectare of main food products[a] in Latin America, 1961/1970 and 1971/1980

Regions	Period	Annual growth rate			Relative contribution to production growth	
		Production %	Harvested area %	Product per hectare %	Harvested area %	Yield per hectare %
Latin America	1961/1980	2.79	1.47	1.30	53	47
	1961/1970	4.26	2.75	1.47	65	35
	1971/1980	1.66	0.61	1.04	37	63
Mexico, Central America, and the Caribbean	1961/1980	3.34	0.58	2.74	18	82
	1961/1970	5.75	2.15	3.53	38	62
	1971/1980	2.65	−0.08	2.73	b	100
Tropical South America[c]	1961/1980	2.81	2.59	0.22	92	8
	1961/1970	4.60	3.73	0.84	81	19
	1971/1980	1.77	1.83	−0.06	100	b
Southern Cone[d]	1961/1980	2.31	0.14	2.17	6	94
	1961/1970	2.52	1.60	0.90	64	36
	1971/1980	0.65	−1.42	2.10	b	100

Source: Valdés, 1983

[a] Cereals, roots and tubers, legumes, and nuts
[b] Negative
[c] Tropical South America includes Bolivia, Brazil, Colombia, Ecuador, Guyana, Paraguay, Peru, Surinam, and Venezuela
[d] The Southern Cone includes Argentina, Chile, and Uruguay

Next we will review how the aggregated agricultural production has evolved, both in crops and in livestock and poultry.

Agricultural Production

Farm production in the countries of the region has varied greatly, at least during the 1970s. Four countries (Brazil, Colombia, Guatemala, and Paraguay) had annual growth rates in the Gross National Farm Product (GNFP) that were above 4%. At the other extreme, six nations (Chile, Haiti, Honduras, Panama, Peru, and Uruguay) had a growth rate lower than 2% in their GNFP. On an average, gross value of agricultural production per capita in Latin America went up 0.8% annually during this period.[8]

It is useful to point out the disparity in the growth rates of different groups of farm products. As López Cordovez indicates, in the decade of the 1970s (1961/1971 and 1978/1980), the fastest growth rates pertained to livestock products, poultry, hogs, eggs, and milk, followed by oil seeds (particularly soybeans), vegetables, and fruits. The growth rate of all these products was more rapid than the population growth, but the growth rates of cereals,[9] beverages, dry legumes, and beef were lower. A third group (including roots, tubers, and vegetable fibers, but not cotton) had a negative growth rate (Table 6). This disparity in growth rates is closely related to the diverse growth rates of the export market and domestic demand. For example, domestic demand and exports of soybeans rose markedly during this period. Fruit, citrus, and apple production has expanded rapidly, but not bananas.

Total crop production rose at an average rate of 3.1% during 1969/1971 and 1978/1980, primarily because of an increase in the availability of farm land and a rise in productivity per cultivated unit. This was due to a 1.7% rate of expansion in farm land and an increase of 1.4% in yields (Table 6). Expansion in farm land was largely in the area planted to soybeans, since land devoted to cereals (not less than 50% of total cultivated land) expanded at a much lower rate (0.7%).[10] Other crops which showed higher than average rates of land expansion were sugar cane, vegetables, and tobacco. There was a negative growth rate in yields for cassava, dry legumes, and vegetable fibers (except for unprocessed cotton) (Table 6).

Agricultural production (food and industrial crops) continues to rise due largely to expansion of cultivated land; nevertheless, the relative contribution of yield to this increase went up between the 1960s and 1970s. In the 1960s, a third of the production growth was a result of yield increases, but in the 1970s this factor accounted for two fifths of the growth in production (López Cordovez, CEPAL-FAO 1982).

Livestock and Poultry Production

Livestock production rose at a faster pace than crop production (around 3.3% annually), and poultry and egg production was the most dynamic (Table 6). Beef production had the slowest growth rate (2.1% annually), lower than the population growth rate. According to Jarvis (1984), the low relative price of beef has made the

8 See López Cordovez, CEPAL-FAO, 1982.

9 Maize production rose at a slower pace than other cereals, and the ratio destined for human consumption diminished.

10 For cereals, land planted to sorghum expanded 2.6% annually, rice fields expanded 2.8% annually and wheat fields, 1.5%, but land planted to maize was reduced.

Table 6. Latin America: annual growth rates for production, area harvested, and average yields, 1969/1971 to 1978/1980

Crop	Volume produced	Harvested area	Yield per hectare
Cereals	2.4	0.7	1.6
Wheat	2.6	1.5	1.1
Rice	3.4	2.1	1.2
Maize	1.3	−0.1	1.4
Soybean	5.5	2.6	2.8
Roots and tubers	−0.7	0.3	−1.0
Potatoes	1.4	−0.3	1.7
Cassava	−1.1	0.7	−1.8
Sugar cane	3.5	2.3	1.1
Dry legumes	0.7	1.1	−0.5
Beans	0.5	1.3	−0.7
Oil seeds	14.2	11.1	2.8
Soybean	25.9	23.6	1.9
Vegetables	3.2	2.1	1.1
Fruits	3.5	0.3	3.2
Bananas	1.9	0.3	1.3
Citrus fruits	7.5	–	–
Apples	7.1	–	–
Beverages and tobacco	2.5	0.9	1.6
Cocoa	4.2	0.5	3.6
Coffee	1.9	0.8	1.0
Tobacco	4.1	2.3	1.7
Cotton	1.4	0.5	0.9
Vegetable fibers	−1.4	−0.2	−1.2
Other crops	5.0	4.0	1.0
Total crops	3.1	1.7	1.4

Livestock products	Volume produced %	Slaughtered and productive animals[a] %
Meats	3.3	
Beef	2.1	2.0[b]
Pork	3.4	3.3[b]
Poultry	9.3	9.3[b]
Other livestock products	3.3	–
Milk	3.2	2.6[c]
Eggs	5.1	4.5[d]
Total livestock production	3.6	2.6
Total agricultural production	3.3	–

Source: Luis López Cordovez, CEPAL-FAO, 1982

[a] Includes increase in yields
[b] Total animals slaughtered
[c] Dairy cows
[d] Total egg-laying hens

intensive use of advanced inputs less profitable than in the United States and Europe.[11] Cattle, sheep, and poultry production, however, is close to world averages. According to Jarvis, in Latin America it has been more profitable to raise cattle production through expanding pasture area than by increasing the number of cattle per hectare.

Determining Factors for Production Increase

Table 8 in the Appendix partly explains the reason for land expansion and the yield increases per hectare by summarizing the changes in the use of key modern inputs. The increase in productivity can be associated with more extensive use of fertilizers, new varieties, and pesticides. Machinery tends to substitute for labor and promotes the expansion of cultivated lands. Increases in the use of tractors and fertilizers are considerable (Table 8), although in the 1970s many countries and the region in general diminished the use of both fertilizers and tractors, compared to the 1950s and the 1960s. This fact confirms what we said before about the evolution of food production (Table 5). The cutback on the use of fertilizers and tractors can be explained by the relative increase in the price of oil and oil derivatives which directly affected the price of fertilizers and fuel, especially right after 1973. Some countries like Brazil and Venezuela established subsidies to compensate for the rise in costs.

To sum it up, agricultural growth has been the result of both area expansion and the more efficient use of farm land. On comparing Latin America with Asia, one might suppose that the former has a more elastic land supply and a less elastic labor supply. Given this, one expects that the increase in Latin American production in comparison to Asia is due mainly to area expansion. This would imply that the most efficient growth strategy would be to raise labor productivity as the agricultural frontier expands. This view of Latin American agriculture, however, is an oversimplification; with few exceptions, the countries of this region have increased land as well as labor productivity. For example, we saw earlier that the use of fertilizers and pesticides rose more rapidly than the use of machinery; this seems inconsistent with a surplus of unutilized land.

Lynam (1980) and other authors think that this inconsistency may only be apparent, and that the simultaneous increase in area and productivity is probably due to the heterogeneous nature of Latin American agriculture. The cost of expanding cultivated lands in most tropical countries of the region is high and many times not as profitable as raising the productivity of the land already in use. The uneven distribution of farm lands is another problem, for the small farmer can only raise production by means of bettering the yield per surface unit. In contrast, large farms that have greater area and hire hand labor invest more in machinery to substitute for labor. This suggests dualism in the land and labor markets.

[11] For Latin America as a whole, production per head of cattle has remained practically unchanged over the last two decades. Nonetheless, the situation varies in individual countries (Jarvis, 1984).

The options of land expansion, mechanization and labor substitution, and, in general, the decisions affecting the relative use of productive factors in agriculture are not really independent of established economic policies; some of these policies have favored (economically) a number of these factors. Thus, subsidized farm credit, currency over-evaluation, and labor legislation on minimum wages and other income have brought about subsidies for the cost of machinery and a relative rise in the price of labor. What is the final impact of economic policies? Do they favor more intensive use of hand labor or of land? These are questions that bear looking into. At any rate, production elasticities of land and labor vary greatly from one country to another.[12] In a study he is now carrying out (1984), V. Elias estimates these coefficients for each of eight Latin American countries using the same methodology and definitions in a Cobb-Douglas framework. His preliminary results indicate that the production elasticity of land has a very wide range of values, fluctuating between 0.1 and 1.3. These results stengthen the hypothesis that it might be inappropriate to generalize on the ways of expanding production.

Lastly, in addition to the impact of economic policies, it should be mentioned that the structure of domestic and foreign demands will affect the derived demand for modern inputs and land in relation to hand labor In this sense, it is possible that there are surplus lands which are potentially advantageous for the production of crops with very limited domestic and no foreign demand, such as cassava.

Livestock and Poultry Trade

Food Security

A basic food security concern in food deficit countries is to achieve stable yearly supplies, especially of cereals. This concern derives from the growing reliance on foreign sources for the provision of basic staples and involves several factors.

The first reason for insecurity is the perceived risk of a lack of reliable access to the foreign supplies required to cover part of domestic consumption. Experience shows that this risk has not materialized in wheat, but the situation is different in the rice and white maize markets, which have "thin" international markets, and are subject to delay and interruptions as well as dependence on a few suppliers.

The second cause for insecurity is the short-term instability of international prices; these do not offer a reliable base for planning imports or establishing long-term domestic production policy. Fluctuations in the price of cereals increased drastically over the decade of the 1970s, in comparison with the 1960s, although annual production variations were not any higher.[13]

The third factor is financial insecurity, that is, the capacity of each country to finance growing and fluctuating food imports because of the unstable supply of hard currency. The economic crisis in Latin America will seriously limit its capacity to finance food imports.

12 Production elasticity is defined as the proportionate change in production caused by proportionate change in inputs.

13 Measured by the coefficient of variation; pertinent data are in Valdés, December, 1983.

It is a fact that imports of livestock and poultry products have risen more rapidly than exports, although the region is still a net exporter. Between 1962/1964 and 1977/1979, exports rose 43% while imports doubled. As a result, the value of total agricultural imports has increased from the equivalent of 25% of the value of agricultural exports at the beginning of the 1960s to 35% at the end of the 1970s (Table 7). Nevertheless, in our opinion, the foreign trade balance in this sector is in itself not a logical indicator of the extent of economic food insecurity. The ratio of food imports to total export revenues from goods and services is a more reliable parameter, for it measures the pressure these imports exert on the balance of payments.

Table 8 presents estimates of the food imports/export revenues (average) ratio for various periods between 1965 and 1981 in six countries of the region. These estimates were made for two alternative definitions of food: in the first (C), food includes cereals only. The second definition of food (A) is much wider and includes vegetable oils, dairy products, fruits, vegetables, and sugar, which are all significant imports. If the restricted definition is used, the average ratio in these countries is low in general, going up to 10% in Brazil and Peru in exceptionally unfavorable years. Estimates by Siamwalla and Valdés (1980) for Asian and African countries indicate that, in cereals, restrictions in hard currency supply are somewhat stiffer in other regions where several countries average more than 10%.[14]

With the wider definition of food, the role of noncereals in Latin America is evident, for they raise the estimated quotient between 50 to 100%. Chile and Peru were the countries with the most severe pressure on the balance of payments, with averages of 11 and 12%. Even so, these figures are much lower than comparable estimates for African and Asian countries, several of which had averages higher than 45%.[15]

As for long-term trends, there are no clear indications that financial pressure has intensified during the period studied; nevertheless, future estimates should take into account the restrictions on the balance of payments due to foreign debt. Recent calculations by Valdés and Alvarez (1984) for Peru illustrate how much a Latin American country depends on imports to satisfy domestic consumption of certain staples. In the last 20 years, imports of edible oils and cereals (maize, wheat, and rice) has increased drastically in that country. Wheat and edible oils imports account for more than 80% of

Table 7. Agricultural exports and imports in Latin America

	1962/1964	1967/1969	1972/1974	1977/1979
		(millions of US$, 1975 prices)		
Total agricultural imports	2,445.9	2,889.8	4,522.8	5,237.0
Total agricultural exports	10,374.9	11,487.3	13,663.8	14,792.1
Imports as % of exports	23%	25%	33%	35%

Source: Valdés, 1983

14 See Table 2 in Siamwalla and Valdés, 1980.

15 See Table 1 in Valdés, 1983.

domestic consumption. Other nations of the region have increased their reliance on food imports, though not to the same degree.

Export Potential

Agricultural exports still account for more than 50% of total income for goods and services exports in Argentina, Brazil, Colombia, Costa Rica, El Salvador, Guatemala, and Dominican Republic. This ratio varies between 25 and 48% in Ecuador, Mexico, and Peru (Valdés, 1983). Thus, changing conditions in world markets and in domestic supply and demand of export farm products have macroeconomic implications for these countries.

In the last decade (1972/1974 to 1977/1979), the most dynamic exports were alcoholic beverages (wine), vegetable oils, fats, and processed foods (Table 9). At the other end of the spectrum, exports of sugar, furs and hides, rubber, oil and processed fats, livestock, meat, textile fibers, chemical fertilizers, and animal oils and fats have gone down in absolute value.[16]

If exports are expressed as a ratio of the regional domestic supply, the exports of wheat, oils, tobacco, poultry meat, and apples have risen, whereas traditional exports such as coffee, cocoa, cotton, sugar, maize, and beef have declined because of the increased domestic demand for these products.

In Latin America, more than 50% of the most dynamic agricultural exports go to industrialized nations which are by far their main market. The only exceptions are vegetable oils and fats, as nearly 50% of these are exported to developing

Table 8. Value of food imports as percentage of return from total exports (using two definitions of food)

Country	1965/1967		1970/1972		1975/1977		1979/1981	
	C/EX	A/EX	C/EX	A/EX	C/EX	A/EX	C/EX	A/EX
Brazil	10	11.6	4	6.2	4	7.1	6	9.4
Chile	4	8.4	4	11.8	7	13.1	4	10.2
Colombia	3	N.A.	3	N.A.	3	4.7	3	6.0
Guatemala	3	N.A.	3	N.A.	3	4.1	3	4.9
Mexico	0.1	N.A.	2	N.A.	5	7.9	4	8.5
Peru	N.A.	N.A.	5	8.4	10	15.2	6.0	8.5

Source: C/EX in 1965/1967 and 1970/1972 from Siamwalla and Valdés, 1980; A/EX in 1965/1967 and 1970/1972 from Valdés, 1983; 1975/1977 and 1979/1981 percentages based on IMF International Financial Statistics (exports) and FAO, Annual Foreign Commerce Reports (imports)

N.A.: Not available

A: Gross food imports include cereals, meats, dairy products, fruits and vegetables, sugar, legumes, tubers, oil seeds and vegetable oil, cocoa beans and cocoa by-products

C: Cereal imports only

EX: Total exports include goods and services and net private transactions which are not obligatory

16 This section on exports and the next one on imports are based on Valdés, 1984.

Table 9. Real growth of Latin American exports to the world

Commodities	1962-1964/1967-1969 %	1967-1969/1972-1974 %	1972-1974/1977-1979 %
Alcoholic beverages	127.3	142.9	117.3
Vegetable oils and fats	−4.6	31.8	97.9
Animal feed	21.9	13.5	52.3
Coffee, tea, cocoa	9.6	−1.5	37.1
Processed foods	102.5	67.3	32.4
Cereals	15.9	−11.9	29.1
Oil seeds	68.1	570.2	28.4
Fruits and vegetables	45.3	14.7	26.2
Miscellaneous raw materials	14.6	12.1	25.4
Dairy products	−52.4	89.8	22.8
Unprocessed fertilizers	−51.7	−20.9	21.7
Tobacco	−4.8	149.0	15.3
Animal fat and oils	58.5	−36.8	−9.1
Chemical fertilizers	−22.2	160.3	−12.9
Textile fibers	−19.8	−17.2	−20.3
Meat	30.3	22.2	−27.7
Live animals	16.6	−5.4	−29.2
Processed oils and fats	12.1	−3.8	−33.4
Rubber	109.3	−11.7	−43.2
Furs and hides	−0.9	−70.2	−50.6
Sugar	20.0	202.2	−57.8

Source: Cuadernos de Economía, Valdés, 1984

Note: Growth rates were estimated using deflated values and reflect the growth from one period to the next; they are not combined annual growth rates

countries and 39% to OECD (Organization of Economic Cooperation and Development) countries. The Latin American market is relatively significant for processed foods and alcoholic beverages, and somewhat less so for vegetable oils and fats (Table 10).

More than 70% of all Latin American farm exports are sold to industrialized countries, and only 7 to 9% are exported to nations of the region. A new market has been created for Latin American products in centrally planned economies in the last few years: in 1977/1979, 10% of all exports were sent to this market which substituted for the traditional market (western industralized nations) to the same proportion.

The export potential of agriculture for Latin America is good. World markets for coffee, oils, vegetable oils, tobacco, beverages, fruits, and vegetables are among the most dynamic, and it would be profitable to stimulate these exports. As Latin America's participation in world agricultural export trade is small (except for coffee), it can maintain its position in the most dynamic international markets without affecting prices.

In 1973/1977, 80% of food exports originated in the Southern Cone, another 14% in Tropical South America, and only 5% in Mexico and Central America (Appendix, Table 10). Between the 1960s and the 1970s, food

Table 10. Destination of Latin American exports, 1977/1979

Commodities	Asia %	Africa %	North Africa and Middle East %	Latin America %	All developing nations %	OECD[a] %	Centrally planned economies %	World (millions US$)
Live animals	0.1	0.2	0.0	21.3	21.5	78.5	0.0	111.2
Meats	0.5	3.5	7.2	7.5	18.6	78.6	2.8	1,070.8
Dairy products	0.0	1.8	2.8	67.6	72.2	27.7	0.1	46.4
Cereals	2.8	1.9	5.1	19.5	29.2	45.4	25.4	1,513.0
Fruits and vegetables	0.2	0.5	2.7	21.4	24.7	71.6	3.7	1,425.6
Sugar	2.2	2.7	11.9	12.3	29.1	66.5	4.4	945.8
Coffee, tea, cocoa	0.1	0.1	1.3	2.4	3.9	88.0	8.1	5,187.0
Animal feed	3.1	0.1	2.2	1.5	6.8	76.0	17.3	1,431.5
Processed foods	0.1	2.8	2.3	39.7	44.9	55.0	0.1	44.9
Alcoholic beverages	0.1	1.7	0.0	24.5	26.3	64.9	8.8	57.5
Tobacco	0.1	0.9	5.5	1.5	8.1	91.2	0.8	293.0
Hides and furs	1.0	0.0	1.5	7.5	10.0	86.9	3.1	35.0
Oil seeds	0.4	0.1	2.2	4.0	7.5	79.9	12.6	747.5
Rubber	0.0	1.2	0.1	60.1	61.4	38.6	0.0	14.5
Textile fibers	10.8	1.0	1.3	4.4	17.5	65.4	17.1	880.4
Unprocessed fertilizers	3.7	0.0	0.0	22.6	26.3	73.7	0.0	27.5
Raw materials	1.4	0.4	6.5	5.3	13.6	86.1	0.2	144.9
Animal fats and oils	0.0	0.3	0.4	63.7	64.4	35.6	0.0	46.5
Vegetable fats and oils	19.1	0.6	13.1	16.0	48.8	39.3	11.9	714.1
Processed fats and oils	1.9	1.8	0.2	15.9	19.9	80.1	0.1	24.9
Chemical fertilizers	1.5	1.4	0.0	59.2	62.1	36.2	1.7	30.1

Source: Cuadernos de Economía, Valdés, 1984

[a] Member countries of the Organization of Economic Cooperation and Development

Note: Estimated by using export value figures deflated (annually) by the UNCTAD export deflator; the first seven columns are Latin American exports to the region as percentages of Latin American exports to the rest of the world, in millions of 1975 US dollars

Table 11. Total value of agricultural imports and exports in Latin America by regions of origin and destination, respectively,[a] 1962/1964 and 1977/1979 (figures in millions of 1975 US$)

Regions	1962/1964				1977/1979			
	Imports		Exports		Imports		Exports	
	Value	%	Value	%	Value	%	Value	%
Latin America	679	28	719	7	1,358	26	1,300	9
Other DC[b]	91	3	191	2	152	3	1,035	7
Total DC	770	32	910	9	1,510	29	2,336	16
OECD	1,672	68	8,876	86	3,716	71	10,942	74
Centrally planned economies	4	–	588	5	11	–	1,514	10
World total	2,446	100	10,375	100	5,237	100	14,792	100

Source: Valdés and Gnaegy, 1984

[a] Imports and exports include fertilizers
[b] DC: Developing countries

exports in Tropical South America doubled, the Southern Cone's increased 56%, while Mexico's and Central America's declined.

Import Demand

Approximately 70% of total agricultural and livestock imports in Latin America come from industrialized nations, and another 26 to 28% come from the region itself. This last ratio has not varied in a long time (Table 11). The region is largely self-sufficient in coffee, tea, sugar, fruits, vegetables, fibers, and meats (Appendix, Table 9).

Cereals have been a dominant group in total regional imports; wheat ranks first, then maize and cereal preparations.[17] Other significant staples are, in order of diminishing importance, chemical fertilizers, fruit and vegetables, dairy products, vegetable oils. There is marked increase in the real value of oil seeds and vegetable oil imports between 1962/1964 and 1977/1979 (Table 12). Food imports in all subregions rose more rapidly than exports in Mexico and Central America, but this does not hold for the two remaining subregions (Appendix, Table 10).

Projections to the Year 2000

The purpose of the following estimates is to project the gap that would result between domestic production and food consumption in Latin America within 15 years, if the trends analyzed in this paper were maintained.[18] This projection assumes that past conditions in relative prices will continue. The projections of demand reflect the probable growth in population and per capita income available for consumption, if other aspects of consumption patterns remain the same.

These projections will be less valid to the degree that technological changes or economic policy modifications take place which affect the growth rate of production, income, or production composition. Nonetheless, they are useful because they help to anticipate deficit or surplus situations and point out the products for investment and promotion.

Projected Regional Food Production

If past production trends are maintained in the future, projected annual growth rate for the main staples to the end of the century is 3.3%. If these projections are compared with similar estimates (using the same method) for other developing regions, Latin America will be the region with the fastest growing food production in the Third World.[19] Of its subregions, Tropical South America will account for close to half of projected production for the year 2000. The other half will be produced equally by the Southern Cone, Mexico, Central America, and the Caribbean (Table 13).

Projected Growth in Food Consumption

Three basic elements affect the projection of the aggregated food demand: expected population growth, aggregated income elasticity of food, and expected increase in the average per capita income. The population is

17 For the region as a whole, net cereal exports went from three million tons in 1961/1965 to a tenth of this volume in 1972/1977 (Paulino, in press). This fact reflects the rapid growth in domestic cereal demand, since domestic production rose during this period.

18 These projections are based on the restricted definition of staples given at the beginning of this paper.

19 Projected growth rate in food production for developing countries as a whole is 2.8%.

Table 12. Agricultural imports and exports in Latin America (millions of 1975 US$)[a]

Commodities	1962/1964		1967/1969		1972/1974		1977/1979	
	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
Cereals	1,148.3	824.2	1,331.2	872.6	1,172.2	1,676.7	1,513.7	1,667.4
Meats	930.4	52.2	1,212.3	65.2	1,481.4	119.4	1,070.8	168.7
Sugar	618.6	54.9	742.5	43.3	2,243.5	74.8	945.8	143.9
Fruits and vegetables	678.0	201.7	985.5	297.2	1,130.0	348.5	1,425.6	456.6
Dairy products	41.8	195.5	19.9	209.8	37.8	317.2	46.4	335.1
Coffee, tea, cocoa	3,505.6	120.1	3,841.9	134.5	3,782.5	153.6	5,187.0	194.2
Beverages and tobacco	112.0	100.8	113.0	129.6	280.7	171.6	350.5	252.3
Processed foods	10.0	45.1	20.3	75.1	33.9	87.4	44.9	130.1
Animal and vegetable oils	372.7	125.6	393.7	188.7	449.5	300.9	785.5	444.6
Live animals	142.4	108.1	166.0	149.4	157.0	85.5	111.2	78.7
Animal feed	679.4	35.8	827.9	61.1	939.6	96.8	1,431.5	150.1
Raw materials[b]	2,059.4	411.2	1,791.2	452.8	1,898.5	565.7	1,822.3	660.7
Total	10,298.6	2,275.2	11,445.4	2,679.3	13,606.6	3,998.1	14,734.5	4,691.4

Source: Cuadernos de Economía, Valdés, 1984

[a] Deflated by the UNCTAD export deflator

[b] Includes oil seeds, hides and furs, raw rubber, textile fibers, and miscellaneous raw materials

Table 13. Production and consumption of basic products in developing nations, by country and subregions; estimates for 1977 and projections to the year 2000 (in millions of metric tons)

Region	1977 estimates			Projections for 2000				
				At 1977 per capita levels			Income growth according to trend	
	Production	Consumption	Net surplus or deficit	Production	Consumption	Net surplus or deficit	Consumption	Net surplus or deficit
Countries	726.2	737.7	−27.5	1,364	1,200	+164	1,438	−74
Latin America	103.5	103.2	+0.2	227	186	+41	232	−5
Mexico, Central America and the Caribbean	24.5	28.8	−4.3	59	58	+[a]	64	−6
Tropical South America	52.5	58.0	−5.5	114	106	+9	145	−31
Southern Cone	26.5	16.4	+10.1	54	22	+32	23	+31

Source: Leonardo Paulino, IFPRI, (in press)

[a] Less than 500,000 tons

Note: Estimates have been rounded off

expected to increase by nearly 12 million every year, that is, at a rate of 2.5% annually; the corresponding estimated rate for developing nations as a whole is somewhat less (2.1%). If the growth of per capita income is projected according to past trends, total food consumption will rise 3.6% between 1977 and the end of the century. It is estimated that approximately 64% of the expected growth in regional food demand will be the result of the rise in population.

Every year aggregated consumption will rise 0.3% more than the projected increase in the main crops analyzed here.[20] While the animal feed use of crops will go up to 4.4% annually, crop use for direct human consumption will rise 2.9% annually, a pace just above the growth in population.

In regard to overall regional conditions, projections indicate that Latin America will go from a net food surplus (in 1977) to a deficit at the end of the century, although this will vary in each subregion. The Southern Cone will have a net surplus of the main staples; Mexico, Central America, the Caribbean, and Tropical South America will have net deficits because their high population growth rates and the high relative increase in per capita income (Table 13). The projections must be used with caution, for the economic crisis of the last two years will not only delay the rise in income, but perhaps will also bring about important changes in economic policy.

Given the serious problems in the balance of payments of a large number of Latin American countries, it is probable that in the future steps may be taken to stimulate imports substitution (especially via the exchange rate). This would mean higher domestic production and, at the same time, lower levels of consumption due to the rise in domestic relative prices that these policies might effect.

Available projections do not include certain crops whose production has been visibly dynamic, such as oil seeds, vegetables, and fruits. Nor do they include livestock products whose consumption is growing at a fast pace, but whose supply (with the exception of poultry and eggs) has not risen at the same rhythm; fewer exportable surpluses or more imports are foreseen (Jarvis, 1984).

Final Comments

The use of the traditional definition of staples (cereals, roots, tubers, and vegetables) presents serious limitations in Latin America; in the first place, there has been a marked diversification in consumption patterns, and the consumption of livestock products, fruits, and vegetables (among others) has risen. Secondly, the new basket of consumer products does not lend itself to aggregation in terms of its calorie content; lastly, if certain livestock products are excluded from the basket, one might underestimate the dynamism of food consumption in the region. Redefining the roster of products used to measure food consumption presents a complex empirical problem, due in part to faulty information.

20 If future growth of per capita income is 1% less than past tendencies, an income elasticity of food demand no higher than 0.3 would mean that the food demand (at constant prices) would rise at the same pace as projected production.

Several authors hold that the nutritional state of Latin America's lowest income groups has worsened. In our opinion, this belief is not based on facts; on the contrary, detailed analyses of how the nutritional state of the poorest strata has evolved in different countries suggest that it may have improved. Even so, this observation does not contradict the serious fact that part of the population suffers from malnutrition. To remedy the situation, it is necessary to implement programs specifically designed to raise low income purchasing power. The main contribution of new farm technology may be that it raises the income of small rural producers. A second contribution of agricultural research is in alleviating the pressures of the balance of payments through increased production of staples that substitute for imports. Contrary to what is commonly held, it is not clear that technology tends to reduce food prices in urban areas, given that many of these products are tradable on the foreign market; thus there is no reason to expect that their prices will be affected.

In the two decades we analyzed, there was a significant change in regional food consumption patterns which was similar to that of developed nations. The notable rise in per capita consumption of meats (especially poultry), eggs, dairy products, and vegetables oils stands out. Though in lesser proportion, per capita consumption of wheat and wheat derivatives, rice, vegetables, and fruits has also gone up. On the other hand, there was a sharp decline in per capita consumption of some of the traditional regional staples, such as cassava, potatoes, and dry legumes (beans). This change in diet makes the exclusive use of the calorie component an inadequate measure of food consumption.

In this study, we have pointed out three factors that determine the modification in food consumption patterns. The first is the accelerated rural-urban migration; it favors the consumption of storable and more processed foods that require less cooking time (i.e., wheat derivatives), and discourages the demand for traditional staples such as cassava, potatoes, and dry legumes. These urban patterns are spreading to rural areas. The second factor, associated with the first, is the effect of increasing family income. We summarized pertinent information for Brazil, Chile, Colombia, and Peru as an example. With rare exceptions, the highest income elasticities correspond to products with an increased participation in diet, such as meats, dairy products, vegetables, fruits, edible oils, and some cereals (i.e., wheat). Products that have diminished in relative importance are the ones with income elasticities that are negative or not different from zero. The third factor is the result of modifications in relative prices because of price policies and, in some cases, technological change (poultry meat, rice, and others). "Low prices" have been maintained for some staples, partly because of their relative importance in the Consumer Price Index. These price and foreign trade policies have accelerated reliance on imports via tariff and exchange rate policies, price controls, direct food consumption subsidies, etc. In many instances, they have also discriminated against the production of crops that compete with imports, or have stimulated their consumption more than other, more neutral economic incentives would have.

There are five significant aspects in the evolution of food production: (a) the high rate of increase in food production during the 1960s and up to the middle of the 1970s in Latin America, compared with the rest of the Third World, and the slowdown of this increase in the second half of the 1970s; (b) the disparity between the rate of increase in food production and export crops; (c) the greater relative importance of productivity changes in determining the production rise in the Southern Cone, Mexico, and Central America during the 1970s, in comparison to the 1960s. In contrast, figures for Tropical South America indicate that, in the 1960s, the change in productivity was both lower and relatively less than in other subregions, and that in the 1970s it was practically zero; (d) livestock and poultry production (especially poultry and eggs) rose at a faster pace than food crops, and consequently, animal feed use of grain grew twice as fast as human consumption of grain. In cattle, the production increase was the result of land expansion more than of increased productivity, and (e) the rapid rise in productivity during the 1960s seems to be linked to the increased use of fertilizers, pesticides and machinery. A possible hypothesis is that the slowdown in productivity during the last part of the 1970s could be the result of the rise in the price of oil and oil derivatives and its effect on the cost of farm inputs; it could, however, also be due to the fall in real exchange rates which, in turn, is the consequence of the massive influx of foreign credit to the region.

To present increased productivity as an alternative to land expansion seems a false dilemma if one considers the region as a whole. The heterogeneity of the region's agriculture, the small producer/business enterprise dualism and the high cost of land expansion in some countries support the position that it is inappropriate to generalize on the ways to raise production. Besides, the road to expansion will undoubtedly be linked to price policies bearing on inputs and products.

Conventional analysis of agricultural trade frequently uses criteria that confuse the issue, such as: (1) "In Latin America, farm exports increase at a lesser pace than imports; this is a sign of poor performance in the agricultural sector"; (2) "The supply of hard currency has been a limiting factor on food imports"; (3) "Trends in Latin America production generally reflect an external imbalance in the agricultural sector", and so forth. In our judgment, none of these statements is valid *per se*.

With regard to the first assertion, there is no logical reason for wanting a commercial balance in each sector; what should be balanced is total goods, services, and capital transfers for the entire economy. As for the second opinion, the supply of hard currency has not been a severe restricting factor on food imports, for the cost of food imports in Latin America has been a relatively small fraction of the supply of foreign exchange in the past. Nevertheless, the present combination of foreign debt and low export prices is a problem in some countries. The third statement about estimates of regional production and balance is not logical. On the one hand, intraregional agricultural trade is a small fraction of farm exports in Latin America; it has risen very slightly since the 1960s and there seem to be no real strategic reasons to seek subsidized mechanisms to promote it. Besides the fact that policy decisions are made by the country, not the region (in contrast with the European Economic Community), the heterogeneity of agricultural trade balances in these countries makes aggregated figures for the region less meaningful.

In the last 20 years, export volume of wheat, oil seeds, tobacco, poultry, and some fruits (apples), as a percentage of national production, has risen. Exports and domestic consumption of vegetable oils and fats have been especially dynamic in Latin America. In contrast, the percentages for coffee, cotton, cocoa, maize, and beef exports declined during the same period, partly as a result of increased domestic consumption. The real (deflated) value of a third group of traditional export products has decreased. This group comprises sugar, furs and hides, rubber, processed oils and fats, livestock, textile fibers, and animal fats and oils.

The cereal group has been dominant among agricultural imports to the region; among these, wheat ranks first, followed by maize. Other important imports are dairy products, fruits and vegetables, vegetable oils, and oil seeds. The rapid growth in real value of oil seeds and vegetable oils imports between 1962/1964 and 1977/1979 was sharp.

If the restricted list of staples adopted by IFPRI (cereals, oil seeds, roots and tubers) is used, projected annual growth of regional food production for the year 2000 is 3.3%. This increase is higher than the projected rise using the same method (2.8%) for the rest of the Third World. The projected annual increase in consumption is approximately 3.6% for the year 2000 (64% of this is due to population growth). If the projected increase in per capita income is reduced by one percentage point, consumption growth goes down from 3.6 to about 3.3%. Animal feed use (4.4% annually) accounts for the main increase in consumption of cereals. Speculatively, even higher rates of increase are projected for oil seeds, vegetables and fruits, and poultry meat consumption.

Because of serious present problems in the balance of payments, exchange rate and price policies are likely to stimulate import substitution via higher levels of local production, and smaller increases in consumption are expected.[21]

This paper did not consider some relevant determining factors of Latin American performance. Among these are the role of local institutions, public spending in agriculture, the effect of economic policies on farm activity, and developments in international markets. Specific studies on each of these topics lead us to conclude that they are very important and that policy adjustments in these fields could bring about significant change in the performance of agriculture in Latin America (Elias, 1981, Cavallo and Mundlak, 1982, Valdés, 1980 and Valdés, 1983).

21 This situation is not reflected in numerical projections of the demand for food imports presented in the text.

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Comment

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The excellent paper prepared by Valdés and Muchnik gives us a different perspective of some common conceptions in the conventional analysis of agricultural sector behavior in Latin America. Their analysis of the nutrition and food security situations is especially relevant, given that some research programs in the region frequently cite these factors as the basis for their existence.

As the authors point out, their work does not touch upon certain aspects that are essential for determining and explaining the performance of agriculture in Latin America (i.e., the role of local institutions, public spending in the sector, international market behavior, and the effects of macroeconomic policies on the sector), but no doubt it is a solid base for the discussions in this workshop.

In the first part of their paper, the authors examine the changes in consumer patterns and their effect on regional diets. They indicate that the food situation in Latin America has improved. In the first place, on an aggregated level, calorie and protein consumption has increased. Secondly, available data on income distribution does not clearly support the hypothesis that consumption levels of the poorest strata have deteriorated. Thirdly, the authors cite three case studies that rigorously and quantitatively refute the hypothesis that the nutrition situation has worsened. One of these studies, in particular, points out that the nutrition problem is the result both of low income and of the ways in which the consumer spends this income. Lastly, the authors show that diet composition in the region is gradually coming closer to food patterns of more developed nations.

Although the nutrition problem in the region has not been solved, the situation has improved noticeably. Thus agricultural research is not justified solely because it achieves results that benefit the diet (beneficial results are the logical consequence of research activities); indeed, its importance is based on more ample grounds than just solving the nutrition problem. This aspect should be taken into account in planning research activities, but it must not be overly emphasized.

Drastic changes in consumer patterns of the region and the factors that are bringing them about indicate that socioeconomic factors (changes in income, migration, changes in employment patterns, etc.) are fundamental in determining the priority research should give certain products. These socioeconomic factors are necessary for predicting changes in the structure of demand and how important different types of products will be in the economies of our countries. I cite as examples the increase in the consumption of wheat and rice in relation to maize; of vegetable oils, fruits and vegetables in relation to roots and tubers; of animal products in relation to vegetable products.

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In the second part of the paper, the authors examine agricultural production behavior and suggest hypotheses about the factors that explain its growth. The broad heterogeneity of Latin American agriculture generates, on the aggregated level, simultaneous increases in cultivated land and in productivity. Although Valdés and Muchnik acknowledge that this conception is an oversimplification, their analysis shows that production growth in the region took place in two distinct periods: during the first, from 1950 to 1960, the rise in production was higher than population growth, and the main reason for it was the increase in cultivated lands. During the second period, in the 1970s, production growth was lower than population growth and the expansion of cultivated lands was much slower.

In the future, increased productivity as the source of agricultural production growth will become more and more important. But as the paper points out, for research, the dilemma of whether to increase growth through land expansion or through greater productivity is not a real dilemma, since in both cases, the role it plays is crucial. Productivity increases basically depend on research results, but expansion of cultivated lands also requires agricultural research, especially if it is to be carried out efficiently, with a minimum risk of failure.

In the third part of their paper, when comparing the supply of agricultural products with domestic demand, the authors review agricultural foreign trade and emphasize food security assessment. Two of the valuable conclusions of this analysis are establishing the true magnitude of the food security problem and identifying the main causes of insecurity.

The level of food insecurity in the region is not as high as in other developing areas, and the primary source of uncertainty is not production, but the financial situation. As with the nutrition problem, care must be taken not to overemphasize, as a research objective, the solution of a problem which is not as serious as it is supposed to be.

Valdés and Muchnik point out that agricultural exports are one of the main sources of foreign currency. This macroeconomic conception is essential for orienting future discussions because it establishes the priority research should be given in our countries today. Due to the effect increased agricultural production has on reducing imports and increasing exports, research contributes, at least partially, to solving the foreign debt problem.

In the last part of this paper, projections of production and consumption levels for Latin America generally confirm the conclusions mentioned before. Although consumption tends to rise at a faster pace than production, the difference is not significant.

Appendix

Table 1. Total calorie intake and calorie intake by food groups in Latin America, 1961/1965 and 1972/1974 (calories per capita per day)

	Minimum calorie requirement	Total calorie intake		Animal products				Vegetable products				Cereals				Roots and tubers				Dry legumes			
		1961/1965	1972/1974	1961/1965		1972/1974		1961/1965		1972/1974		1961/1965		1972/1974		1961/1965		1972/1974		1961/1965		1972/1974	
				Cal	%	Cal	%	Cal	%	Cal	%	Cal	%	Cal	%	Cal	%	Cal	%	Cal	%	Cal	%
Mexico	2,330	2,570	2,692	285	11.0	329	12.2	2,284	88.8	2,362	87.7	1,313	51.0	1,364	50.6	22	0.8	20	0.7	175	6.8	153	5.6
The Caribbean	2,260	2,123	2,241	240	11.3	269	12.0	1,862	87.7	1,973	88.0	820	38.6	856	38.1	141	6.6	152	6.7	112	5.2	115	5.1
Cuba	2,310	2,431	2,732	449	18.4	555	10.3	1,982	81.5	2,177	79.6	976	40.1	1,183	43.4	145	5.9	127	4.6	106	4.3	112	4.0
Costa Rica	2,240	2,200	2,512	339	15.4	409	16.2	1,862	84.6	2,104	83.7	881	40.0	950	37.8	38	1.7	28	1.1	93	4.2	95	3.7
El Salvador	2,290	1,819	1,885	237	13.0	202	10.7	1,581	86.9	1,683	89.2	998	54.8	1,057	56.0	11	0.6	16	0.8	93	5.1	76	4.0
Guatemala	2,190	1,956	1,989	197	10.0	192	9.6	1,759	89.9	1,787	89.8	1,245	63.6	1,181	59.3	6	0.3	5	0.2	101	5.1	104	5.2
Honduras	2,260	1,937	2,051	227	11.7	240	11.7	1,709	88.2	1,811	88.2	1,081	55.8	1,090	53.1	32	1.6	41	1.9	112	5.7	92	4.4
Nicaragua	2,250	2,244	2,383	352	15.6	363	15.2	1,892	84.3	2,020	84.7	1,053	46.9	1,097	46.0	21	0.9	31	1.3	183	8.1	192	8.0
Panama	2,310	2,342	2,332	370	15.7	401	17.1	1,971	84.1	1,930	82.7	1,112	47.4	942	40.3	73	3.1	93	3.9	70	2.9	38	1.6
Central America	2,245	2,107	2,107	257	12.7	262	12.4	1,759	87.2	1,844	87.5	1,097	54.3	1,085	51.4	21	1.0	26	1.2	107	5.3	99	4.6
Venezuela	2,470	2,225	2,399	416	18.6	452	18.8	1,809	81.3	1,946	81.1	770	34.6	880	36.6	128	5.7	91	3.7	76	3.4	53	2.2
Bolivia	2,390	1,638	1,860	241	14.7	276	14.8	1,397	85.2	1,583	85.1	750	45.7	798	42.9	246	15.0	287	15.4	18	1.0	18	0.9
Chile	2,440	2,578	2,738	432	16.7	451	16.4	2,146	83.2	2,285	83.4	1,217	47.2	1,336	48.7	118	4.5	100	3.6	55	2.1	64	2.3
Colombia	2,320	2,142	2,164	376	17.5	337	15.5	1,766	82.4	1,827	84.4	696	32.4	681	31.4	150	7.0	176	8.1	41	1.9	42	1.9
Ecuador	2,290	1,895	1,086	306	16.1	345	16.5	1,589	83.8	1,741	83.4	575	30.3	679	32.5	154	8.1	178	8.5	105	5.5	60	2.8
Peru	2,350	2,255	2,328	347	15.3	362	15.5	1,968	84.6	1,964	84.3	900	39.9	915	39.3	318	14.1	301	12.9	89	3.9	56	2.4
Andean Countries	2,350	2,179	2,269	359	16.4	359	15.8	1,819	83.4	1,909	84.1	833	38.2	863	38.0	193	8.8	202	8.9	59	2.7	49	2.1
Brazil	2,390	2,420	2,540	335	13.8	339	13.3	2,086	86.1	2,201	86.6	866	35.7	903	35.5	285	11.7	260	10.2	212	8.7	202	7.9
Argentina	2,650	3,247	3,280	956	29.4	944	28.7	2,291	70.5	2,336	71.2	1,062	32.7	996	30.3	176	5.4	155	4.7	24	0.7	16	0.4
Paraguay	2,310	2,512	2,723	506	20.1	469	17.2	1,961	78.0	2,253	82.7	742	29.5	874	32.0	519	20.6	459	16.8	107	3.9	143	5.2
Uruguay	2,670	2,938	2,977	1,224	41.6	1,032	34.6	1,714	58.3	1,945	65.3	859	29.2	1,064	35.7	133	4.5	114	3.8	26	0.8	20	0.6
Latin America	2,380	2,439	2,544	401	16.4	405	15.9	2,036	83.4	2,139	84.0	963	39.4	1,003	39.5	178	7.2	165	6.4	134	5.4	122	4.7

Source: CIAT, 1980, based on FAO, Monthly Bulletin of Agricultural Economics and Statistics

Appendix

Table 2. Average annual rate of rural and urban population growth in Latin America, 1950/1960, 1960/1970, and 1970/1976

	Annual growth (%)					
	1950/1960		1960/1970		1970/1976	
	Rural	Urban	Rural	Urban	Rural	Urban
Mexico	1.52	4.88	1.85	4.81	1.79	4.66
The Caribbean	1.43	4.50	1.10	6.10	−1.06	5.90
Costa Rica	3.68	4.16	2.23	4.95	1.71	3.86
El Salvador	2.45	3.34	3.25	3.69	2.97	3.49
Guatemala	0.98	5.47	1.73	4.13	1.17	3.79
Honduras	2.42	6.18	3.11	4.14	−1.56	5.33
Nicaragua	1.48	4.08	1.67	4.50	0.66	4.20
Panama	2.03	4.39	2.10	4.66	1.58	3.98
Central America	2.53	3.20	2.06	4.86	1.09	4.00
Chile	0.13	3.68	−0.49	3.48	−3.21	2.41
Colombia	0.90	6.75	1.56	4.18	−2.20	4.47
Peru	–	–	0.05	5.12	0.90	4.60
Venezuela	−0.26	5.69	−0.82	4.92	0.92	2.48
Andean Countries	0.85	5.22	0.83	4.41	0.75	3.25
Brazil	1.43	5.82	0.57	4.52	0.10	4.93
Paraguay	2.12	2.67	2.42	3.22	–	–
Plata River Basin countries	1.36	3.52	−0.71	2.15	−0.34	1.63
Latin America	1.14	4.84	0.89	4.16	0.91	3.71

Source: Lynam, 1980, based on USDA and IDB

Appendix

Table 3. Peru: Income elasticities of consumption by food subgroups as related to total per capita family expenditures[a]

Range of elasticity quotients	Greater Lima		Rural	
0.0 - 0.3	Nuts	0.05		
	Cereals	0.07		
	Legumes	0.09		
	Roots and tubers	0.12		
	Fats: oil	0.18		
	Fish and sea food	0.18		
	Vegetables	0.25		
	Sugars	0.27		
0.3 - 0.6	Meats	0.37	Fish and sea food	0.34
	Fruits	0.50	Cereals	0.58
	Eggs	0.60		
0.6 - 1.0	Dairy products	0.65	Oils: fats	0.61
	Beverages	0.70	Vegetables	0.62
			Eggs	0.63
			Legumes	0.68
			Roots and tubers	0.82
			Meats	0.86
			Fruits	
1.0 - 1.5			Dairy products	1.07
			Sugars	1.06
			Beverages	1.36

Source: Amat y León and Curonisy, 1981, Tables 28 and 29

[a] Information is also available for large populated centers and cities

Appendix

Table 4. Expenditure elasticities of demand for selected commodities, Santiago, Chile, 1977/1978

Commodities	Expenditure elasticity
Bread, cereals, and starches	0.16
Bread	0.22
Rice	0.33
Noodles	0.41
Meats	0.69
Beef	1.11
Lamb	0.22
Pork	0.88
Poultry	1.53
Fish, sea food and sea products	0.57
Fresh fish	0.36
Dairy products and eggs	0.77
Milk and cream	0.79
Eggs	0.56
Oils, fats and vegetable fats	0.23
Butter	0.52
Oil	0.53
Fruits	0.74
Lemons	0.66
Oranges	0.79
Pears	1.03
Grapes	0.90
Peaches	0.99
Vegetables, potatoes, and tubers	0.31
Potatoes	0.20
Garlic	0.52
Onions	0.31
Legumes	0.26
Beans	0.26
Lentiles	0.68
Chick peas	0.34
Sugar	0.07
Coffee	1.19
Tea	0.26

Source: Department of Agrarian Economics, Catholic University; based on the III Survey of Family Budgeting 1977/1968, Santiago from INE

Appendix

Table 5. Income elasticities of consumer demand for selected commodities, Colombia, 1981

Commodities	Income elasticity per quintile I	II	III	IV	V	Average
Beef	2.46	1.56	1.28	0.86	−0.39	0.66
Pork	1.66	2.00	2.12	2.27	2.76	2.36
Poultry	0.48	1.27	1.54	1.90	3.03	2.09
Fish	1.55	1.53	1.52	1.52	1.48	1.51
Eggs	1.30	0.88	0.73	0.50	−0.34	0.37
Dairy products	1.92	1.31	1.10	0.82	−0.06	0.67
Rice	0.89	0.87	0.85	0.82	0.74	0.83
Beans	0.96	0.58	0.43	0.23	−0.55	0.11
Cassava	1.17	0.73	0.57	0.33	−0.55	0.20
Fruits	1.84	1.28	1.09	0.84	0.64	0.70
Fats	1.39	0.94	0.77	0.53	0.37	0.40
Bread	1.74	1.22	1.05	0.81	0.07	0.69
Potatoes	−0.02[a]	−0.03[a]	−0.04[a]	−0.04[a]	−0.05[a]	−0.04[a]
Peas	2.63	1.89	1.64	1.30	0.24	1.12
Maize	1.04	0.75	0.64	0.49	0.09	0.40
Vegetables	1.40	0.91	0.76	0.53	−0.15	0.42
Plantains	1.04	0.64	0.48	0.26	−0.56	0.14

Source: CIAT, 1984

[a] Not significant ($a = 0.2$)

Appendix

Table 6. Weights of several commodities in the cost of living index of selected Latin American countries (percentages)

Commodities	Argentina	Brazil[a]	Chile	Colombia[b] Workers	Colombia[b] Emp.	El Salvador	Urban Guatemala	Paraguay	Peru[c]	Dominican Republic[d] Urban	Dominican Republic[d] Rural	Uruguay	Venezuela
Cereals and starches	4.95	9.43	0.05	10.12	5.90	10.68	11.21	11.4	6.77	6.7	13.6	5.57	–
Wheat	4.66	4.44	6.96	4.81	3.20		6.52	–	4.0				1.17
Bread	2.56	3.00	5.03	3.27	2.12		5.95	1.3	2.64				0.04
Flour	0.16	0.06	0.37	0.45	0.19		–	0.6	–				–
Noodles	0.60	–	0.92	–	–		0.57	2.3	–				–
Others	1.34	1.38	0.64	1.09	0.89		–	5.5	1.35				–
Rice	0.25	4.38	0.76	3.57	1.62		1.11	1.4	2.05				0.54
Maize[e]	0.04	0.28	0.17	1.49	0.79		3.30	–	0.12				0.44
Others	–	0.33	0.15	0.25	0.29		0.27	0.3	0.61				–
Meats and meat by-products	15.15	5.70	9.38	9.80	7.92	6.73	9.79	15.4	9.45			11.15	–
Beef	10.40	N.A.	6.14	9.86	6.87		6.35	15.0	3.16				–
Pork	0.39	0.47	0.22	–	0.32		0.75	0.2	0.26				0.61
Lamb	0.13	N.A.	0.13	–	–		–	–	0.57				–
Chicken	1.72	1.99	1.72	–	0.64		1.83	0.2	4.29	8.0	11.7		1.13
Sausage	0.87	0.77	0.87	–	0.09		0.35	–	–				–
Others	0.30	N.A.	0.30	–	–		0.51		1.17				–
Dairy products and eggs	5.72	4.01	4.32	7.74	5.88	7.96	7.78	4.70	4.54	5.4	4.5	7.69[f]	–
Milk	2.00	2.60	2.31	5.94	3.63		3.70	3.30	3.11				1.23
Cheese	1.71	0.31	0.74	–	0.39		0.53	0.60	0.35				0.78
Eggs	1.26	1.10	0.97	1.80	1.86		2.84	0.80	1.06				0.67
Others	0.75	–	0.30	–	–		0.70	–	0.02				–
Oils, lard, and fats	1.53	2.90	2.47	3.05	2.05	1.70	2.11	3.40	2.02	3.7	6.4		–
Oils	0.95	1.64	1.45	3.05	1.60		1.14	3.4	1.47				–
Margarine	0.06	0.64	0.41	–	0.28		0.37	–	0.32				0.03
Butter	–	0.20	0.50	–	0.17		–	–	0.22				0.26
Others	0.52	0.42	0.11	–	–		0.60	–	0.01				–
Fruits	2.48	1.48	2.53	2.45	3.23	5.43	2.36	2.0	2.73	3.3	3.9	8.50	–
Vegetables, legumes, and tubers	3.22	4.51	4.96	10.91	6.39		5.40	6.6	5.72	4.7	9.0		–
Beans	0.22	1.70	0.39	0.80	0.34		1.79	0.3	0.51				0.01
Potatoes	0.67	0.73	1.10	4.55	2.01		0.69	0.7	1.57				0.39
Cassava	–	0.06	–	0.61	0.29		–	1.9	0.10				0.04
Onions	0.27	0.30	0.61	0.73	0.43		–	0.9	0.42				0.26
Others	2.26	1.72	2.86	4.22	3.32		2.92	2.8	3.12				–
Sugar	0.81	0.48	1.30	1.01	0.91		1.72	3.0	1.07	1.3[g]	1.6[g]		0.48
Coffee	0.49	0.94	0.62	1.19	0.99		1.55	0.9	0.67				0.94
Nonalcoholic beverages	1.34	0.90	1.34	0.72	0.47	3.13	0.74	–	0.38	1.6	1.9		0.90
Alcoholic beverages	1.28	1.24	1.28	0.34	0.80		1.46	0.7	0.56	–	–		1.24

Source: Bulletins from the General Office of Statistics (Argentina, Chile, Colombia, El Salvador, Guatemala, Peru, Uruguay, and Venezuela), Central Bank (Dominican Republic and Paraguay), and IBGE (Brazil) obtained through CEPAL, design by the authors

[a] Rio de Janeiro
[b] Bogota
[c] Greater Lima
[d] Santo Domingo
[e] Includes maize products
[f] Includes dairy products, eggs, and oils
[g] Includes syrups and sweets
N.A. = Not available

Appendix

Table 7. Wheat producer and consumer subsidies as percentages of import prices (cif), 1965/1982

Year	Production subsidy[a] %	Consumer subsidy[b] %
1965	29.0	−13.8
1966	63.1	3.6
1967	55.8	6.8
1968	57.7	2.3
1969	55.6	6.5
1970	58.5	−13.0
1971	37.8	0.0
1972	24.9	7.5
1973	−7.2	38.4
1974	−8.2	59.3
1975	17.4	55.1
1976	24.1	61.2
1977	95.3	37.3
1978	58.4	52.9
1979	13.0	72.0
1980	−1.9	83.8
1981	20.9	62.6
1982	61.0	42.3

Source: Calegar and Schuh, 1984

[a] Nominal rate of producer subsidy
[b] Nominal rate of consumer subsidy

Appendix

Table 8. Annual growth rate of tractors in stock and fertilizer use, 1950/1978

	Tractors			Fertilizers		
	1950/1960	1960/1970	1970/1978	1950/1960	1960/1970	1970/1977
Mexico	7.9	7.8	3.8	23.8	12.3	0.8
The Caribbean	7.6	12.3	3.9	11.6	8.6	1.6
Central America	13.3	6.6	3.7	13.0	14.2	8.5
Venezuela	14.1	4.8	3.6	22.0	10.9	22.1
Andean Countries	9.6	2.9	2.5	13.4	7.0	4.9
Brazil	22.0	10.5	7.8	13.4	13.9	18.5
Plata River	7.5	4.8	1.2	9.6	13.1	−0.5
Latin America	9.8	6.9	4.0	12.4	11.2	9.8

Source: CIAT, 1980

Appendix

Table 9. Origin of Latin American imports, by commodities, 1977/1979

Commodities	Asia	Africa	North Africa and Middle East	Latin America	All developing countries	OECD[a]	Centrally planned economies	World (millions of US$)
				(percentages)				
Live animals	0.0	0.0	0.0	37.6	37.6	62.4	0.0	78.7
Meat	0.0	0.0	0.0	50.2	50.2	49.8	0.0	168.7
Dairy products	0.0	0.0	0.0	10.3	10.3	89.6	0.1	335.1
Cereals	2.2	0.0	0.1	16.9	19.2	80.4	0.4	1,667.4
Fruits and vegetables	0.3	0.1	0.4	65.7	66.5	33.3	0.2	465.6
Sugar	0.1	0.0	0.0	77.7	77.8	22.2	0.0	143.9
Coffee, tea, cocoa	4.2	1.8	0.1	79.8	85.8	14.2	0.0	194.2
Animal feed	0.0	0.2	0.0	17.3	17.5	82.3	0.2	150.1
Prepared foods	0.2	0.0	0.0	14.9	15.1	84.9	0.0	130.1
Alcoholic beverages	0.0	0.0	0.0	7.5	7.6	92.4	0.0	189.0
Tobacco	0.1	0.0	0.1	9.2	9.4	90.3	0.3	63.3
Furs and hides	0.0	0.0	0.0	4.5	4.6	95.4	0.0	63.6
Oil seeds	0.0	0.1	0.0	15.3	15.3	84.7	0.0	235.7
Rubber	23.0	0.2	0.0	5.2	28.4	71.6	0.0	195.1
Textile fibers	2.8	0.3	0.8	58.9	62.7	37.2	0.1	81.1
Unprocessed fertilizers	0.0	0.0	56.7	8.4	65.1	34.9	0.0	74.1
Raw materials	1.9	0.2	0.2	0.9	13.2	86.1	0.7	85.2
Animal fats and oils	0.0	0.0	0.0	23.8	23.8	76.2	0.0	115.3
Vegetable fats and oils	1.4	0.0	0.0	37.0	38.5	61.5	0.0	310.9
Processed fats and oils	0.0	0.0	0.0	23.7	23.7	76.3	0.0	18.4
Chemical fertilizers	1.5	0.0	0.2	4.7	6.4	93.1	0.5	471.5

Source: Cuadernos de Economía, Valdés, 1984

[a] Member countries of the Organization of Economic Cooperation and Development

Note: Estimated by using export value figures deflated (annually) by the UNCTAD import deflator; the first seven columns are Latin American imports from the region as percentages of Latin American imports from the rest of the world, in millions of 1975 US dollars

Appendix

Table 10. Total exports, imports, and net exports of basic products from developing countries, by regions, 1961/1965 and 1973/1977 (averages)

	Exports 1961/1965 (million tons)	Exports 1973/1977 (million tons)	Change %	Imports 1961/1965 (million tons)	Imports 1973/1977 (million tons)	Change %	Net exports[a] 1961/1965 (million tons)	Net exports[a] 1973/1977 (million tons)	Annual growth rate (%) 1961/1965 Exports	Annual growth rate (%) 1973/1977[b] Imports
Latin America	10.03	15.32	52.8	6.29	13.94	121.7	3.74	1.38	3.6	6.9
Mexico and Central America	1.05	0.80	−23.5	1.98	5.76	190.7	−0.94	−4.96	−2.2	9.3
Tropical South America	1.00	2.11	109.9	3.93	6.99	78.1	−2.92	−4.89	6.4	4.9
Southern Cone	7.98	12.42	55.7	0.38	1.19	213.1	7.60	11.23	3.8	10.0

Source: Leonardo Paulino, IFPRI (in press)

[a] Exports less imports; figures have been rounded off
[b] Calculations based on the middle years of the indicated period

Agricultural Research in the Public Sector of Latin America: Problems and Perspectives

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Introduction

In the last two decades, Latin American agriculture has shown surprising dynamism. Not only have factor productivity and production of important crops increased, but national research and extension systems have been consolidated in most of the countries in the region. Though outstanding, institutional development has been uneven quantitatively and in the organizational forms adopted. With the exception of English-speaking Caribbean countries, however, the dominant organizational model is the national agricultural research institute.

Institutes of this type were established at the end of the 1950s and are a major characteristic innovation of Latin America. They depend on the central government but, at least in the spirit of their creation, have a high degree of autonomy and an ambitious mandate that covers a wide range of regions, crops, and problems. Their rapid development and leadership role in the agrarian modernization of Latin America is a fact.

One result of this modernization process and of the increasing importance of technology in agrarian production is the considerable growth of other public and private institutions involved in technology development and transfer. Because of the emergence of this multi-institutional model, the growing complexity of agricultural technology, and the rise of the private sector, the nature, priorities, and organizational forms of the institutes should be carefully reassessed. This reassessment is particularly relevant to international centers and technical assistance programs, for it creates new needs as well as new possibilities for greater interinstitutional integration and the consolidation of national programs.

This paper analyzes these three related themes. The first two sections describe and evaluate national research systems and their resources, then identify problems related to public sector research. The next section presents possible organizational solutions to the enumerated problems, and in so doing, sketches a new organizational model. The fifth section analyzes national programs (as they relate to international research centers) and suggests complimentary activities. The last section returns to the subject of financing national programs: the current external debt crisis in most Latin American countries affects technical and financial assistance programs aimed at the consolidation of national research systems.

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National Programs

The Dominant Model: National Research Institutes

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 form of public sector participation. 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 experiment 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 that depend directly on the agricultural ministries. Eventually, research activities were almost entirely centralized in the ministries where, in most cases, they were taken over by the general directorships.

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 the ones that determine agricultural policy for the effective development of the production process (prices, credits, services and others) (Trigo *et al.*, Chap. 7; Sampei, 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 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 assimilation 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 developing 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.[1] 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 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

1 T. W. Schultz summarized this idea in his book *Transforming Traditional Agriculture*; it served as the basis for U.S. foreign aid policy implemented in 1951 and known as Point IV.

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 Agricultural Research (INIA) in Mexico in 1960, the Agricultural Research and Promotion Service (SIPA) in Peru, the Columbian 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.[2]

The institutional model, though decentralized and autonomous, covers a wide range of products, regions, and producers, while conforming to the view that agricultural technology is a public responsibility, hence a monopoly of the State.[3]

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 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 of Agricultural Research (EMBRAPA) was created. This organization has certain characteristics that set it apart from the other institutes mentioned, such as that it does not carry out extension, an activity which was assigned to a twin organization, 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.[4]

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2 INIAP in Ecuador and INIA in Mexico present slight variations on the basic model, since the transfer of technology is not formally one of the functions of the institutes.

3 Two examples of this point of view are: the structure of the Board of Directors of ICA, which does not include trade union representatives (Piñeiro *et al.*, Chapter 6); and the tendency of INTA technicians to assume the role of expressing the "social demands" for technology, this being interpreted as different from that of agricultural producers (CIAP 6).

4 Though the trend to create decentralized autonomous institutes reached its peak from the end of the 1950s through the early 1960s, it continued into the 1970s with the founding of the Bolivian Institute of Agricultural Technology (IBTA), the Institute of Science and Agricultural Technology (ICTA) in Guatemala, the National Institute of Agricultural Technology (INTA) in Nicaragua, and finally the National Institute of Agricultural Research (INIA) in Peru.

From 1960 on, there was 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 can be found 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 Britain 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.

Evolution of Resources Allocated to Agricultural Research

Budget support and the availability of human resources for research development are aggregated indicators of the priority assigned to such development by a given government and of the adequacy and potential of existing infrastructures. We will examine these variables by regions, noting specific cases according to available information.

Table 1 presents agricultural research expenditures expressed as percentages of the Gross Agricultural Product in various regions of the developing world in 1975 and for countries of Latin America in 1976 and 1980. In general terms, four observations can be made.

First, resources allocated to agricultural research in the developing world are markedly less than those invested in more developed countries, which come to more than 1.5% of the value of production (Boyce and Evenson). Secondly, Latin America's investment is comparable to other regions and markedly superior to Asia's where the history and concentration of international agricultural research efforts have been similar. Thirdly, there is great disparity among Latin American countries, which cannot be explained by the differences in income levels nor by the size and importance of their agricultural sectors. If low-income countries which have consistently lower levels are eliminated, the remainder present totally asystematic variations. Finally, in most countries there is a notable increase in the funds assigned to research between 1975 and 1980.

In a similar analysis grouping Latin American countries by regions (excluding the Caribbean, for lack of information), the situation is more in accordance with research institutions' degree of development and with how old they are. The situation in the southern part of the continent (Argentina, Brazil, Chile, and Uruguay) and in the Andean Zone (Colombia, Ecuador, Peru, and Venezuela) presents higher standards and is more homogeneous than in Central America. Paraguay in the south and Bolivia in the Andes are exceptions that can be explained by the late development of their institutional infrastructures.

Table 1. Latin America and other developing regions: cost of agricultural research expressed as percentages of the gross agricultural product, 1975 and 1980

Regions	Regional average	Developing regions: Low income	Developing regions: Middle income	Developing regions: High income	Countries	Latin America: Low income 1975	Latin America: Low income 1980	Latin America: Middle income 1975	Latin America: Middle income 1980	Latin America: High income 1975	Latin America: High income 1980
Asia	0.16	0.15	–	0.18	Bolivia	0.09	0.34	–	–	–	–
					Haiti	0.01	–	–	–	–	–
Middle East	0.31	0.29	0.46	0.26	Brazil	–	–	0.54	1.15	–	–
					Chile	–	–	1.19	0.81	–	–
West Africa	0.57	0.65	0.32	–	Colombia	–	–	0.50	0.64	–	–
					Costa Rica	–	–	0.40	0.24	–	–
					Ecuador	–	–	0.41	0.35	–	–
East Africa	0.43	0.38	1.47	–	El Salvador	–	–	0.18	0.50	–	–
					Guatemala	–	–	0.09	0.39	–	–
Latin America	0.43	0.04	0.42	0.52	Honduras	–	–	0.15	0.16	–	–
					Jamaica	–	–	0.58	0.23	–	–
					Mexico	–	–	0.16	1.36	–	–
Total 65 countries	0.31	–	–	–	Nicaragua	–	–	0.34	0.27	–	–
					Panama	–	–	0.90	5.33	–	–
					Paraguay	–	–	0.12	0.28	–	–
					Peru	–	–	0.50	0.33	–	–
					Argentina	–	–	–	–	0.54	1.64
					Uruguay	–	–	–	–	0.44	0.59
					Venezuela	–	–	–	–	0.49	1.32

Source: a) Data by regions and for Latin American countries in 1975: Oram, P., 1978
b) For Latin American countries in 1980: Oram, P., 1984

Tables 2 and 3 present the status and evolution of financial and human resources in selected years between 1960 and 1980 for the major subregions of Latin America and the Caribbean.[5] Though an important indicator, aggregated information can camouflage different institutional situations. For this reason, a separate table presents the information on Brazil, Mexico, and the Dominican Republic which, because of their size, dominate the subregional totals.

In general terms, there is a marked increase in human and financial resources allocated to agricultural research in the region. The resulting panorama is somewhat different if the subregions are analyzed separately, and still more if countries are considered individually.

Evident at the subregional level: a) the apparent departure from the trend noted in the Southern Zone, where aggregated budgets for the four countries, after peaking in 1974, were reduced by 10%; b) the flattening of this trend in the Andean region in the second half of the 1970s, as the aggregated budgets continued to rise at a rate much lower than in the early 1970s.[6] Central America, Brazil and Mexico present the opposite situation, showing a sustained growth throughout the period.[7] Conditions in the Caribbean are similar to those in South America, although the doubtful quality of available information precludes definite conclusions.

Human resources for agricultural research (Table 3) are slightly different from financial resources; the main difference is that subregional totals for the Southern Zone continued to grow after 1974. Comparing financial and human resources, between 1970 and 1980, research funds available per man-year drop slightly in the Southern Zone and remain stable in the Andean Zone. Again, Central America, Brazil, Mexico, and Panama register a different pattern with noticeable increases. The aggregated investment panorama is clarified by analyzing available information for each country.

Of the 16 countries for which there is information of some length, eight (Costa Rica and El Salvador in Central America; Colombia, Ecuador, Peru, and Venezuela in the Andean Zone; and Argentina and Uruguay in the Southern Zone) reached budgetary peaks which then dropped. In some cases, the differences between the extremes reached 50%. Generally, there were marked annual variations suggesting budget instability (Table 4). A fact which deserves mention is that most unstable situations are found in countries with older institutions (Argentina, Colombia, Ecuador, Peru, Uruguay, Venezuela, etc.).

The decline of postgraduate programs organized and financed by the agricultural research institutes and supported by substantial external

5 In grouping countries by subregions, criteria used by IICA in its zoning have been followed.

6 This changes if you exclude Bolivia, which is responsible for total increases between 1974 and 1980 that rose from less than US$500,000 to more than US$7,000,000.

7 It should be taken into account that Central American countries and Brazil began institutional development (creation of the institutes) as recently as 1970. Thus this is a period of consolidation which, in the rest of the countries of South America, took place in the 1960s.

Table 2. Latin America and the Caribbean: financial resources (in thousands of 1975 US$) allotted to agricultural research, selected years between 1960/1980

Subregion[a]	1960	1965	1970	1974	1980
Southern Zone	33,956[b]	32,728	34,795[c]	47,726[d]	43,747[e]
Brazil	8,280[f]	15,533[g]	24,178[h]	32,879[i]	116,797
Andean Zone	15,629[j]	20,000[k]	43,053[l]	57,392[ll]	61,910[m]
Panama and Central America	4,409[n]	4,967[o]	4,904[p]	6,318[q]	10,215
Mexico	4,666[r]	5,218	9,723	14,637[s]	43,357[t]
The Caribbean	1,536[u]	1,536[v]	3,273[w]	2,933[x]	2,124[y]
Dominican Republic	440[z]	496[z]	490[z]	2,278	1,642
Latin America and the Caribbean	68,916	80,478	120,416	164,163	279,792

Source: Piñeiro and Trigo

a. Southern Zone: Argentina, Uruguay, Paraguay, and Chile; Andean Zone: Bolivia, Peru, Ecuador, Colombia, and Venezuela; Central America: Costa Rica, Nicaragua, Honduras, El Salvador, and Guatemala; the Caribbean: Guyana, Surinam, Jamaica, Haiti, Barbados, Grenada, and Trinidad Tobago
b. 1961 data for Chile
c. 1971 data for Paraguay
d. 1973 data for Chile and Uruguay; 1972 data for Paraguay
e. 1979 data for Argentina
f. 1962 data
g. Estimates based on Boyce and Evenson
h. 1972 data
i. 1973 data
j. 1962 data for Bolivia, Venezuela, and Peru; 1965 data for Ecuador
k. 1962 data for Bolivia
l. 1972 data for Bolivia, and 1969 data for Venezuela
ll. 1973 data for Bolivia and Ecuador; 1976 data for Venezuela and Peru
m. 1979 data for Colombia
n. 1962 data for Nicaragua and Guatemala; 1963 data for Honduras
o. 1966 data for El Salvador, 1962 data for Guatemala, and 1961 data for Panama
p. 1965 data for Honduras and Nicaragua, and 1973 data for Guatemala; the figure for Panama was estimated at US$600,000
q. 1973 data for El Salvador, and 1976 data for Honduras and Panama; the figure for Nicaragua was estimated at US$1,000,000
r. 1962 data
s. 1972 data
t. 1979 data
u. 1965 data for Barbados, Jamaica, Surinam, Grenada, and Trinidad Tobago; figure for Guyana was estimated at US$250,000
v. 1960 data
w. 1972 data for Barbados, Jamaica, Surinam, Grenada, and Trinidad Tobago, 1973 data for Guyana, and 1976 data for Haiti
x. 1976 data for Barbados and Haiti, and 1972 data for Jamaica and Trinidad Tobago
y. 1978 data for Haiti and Guyana, and 1974 data for Surinam and Grenada
z. These figures were estimated as 10% of the total for Panama and Central America

Table 3. Latin America and the Caribbean: human resources (professional personnel) working on agricultural research, selected years from 1960/1980

Subregion[a]	1960	1965	1970	1974	1980
Southern Zone	365[e]	816	1,045[c]	1,196[d]	1,364
Brazil	200[e]	500[f]	764	2,000	2,935
Andean Zone	387[g]	643	1,294	1,694	1,843[h]
Panama and Central America	144[i]	305[j]	283[k]	1,000	1,079
Mexico	190[e]	279[m]	551	1,000	1,079
The Caribbean	64[e]	96	157[n]	228[o]	198[p]
Dominican Republic	3[e]	5	12[n]	35[q]	99
Latin America and the Caribbean	1,353	2,644	4,106	6,486	7,901

Source: Piñeiro and Trigo

a. The Southern Zone includes Argentina, Uruguay, Paraguay, and Chile; the Andean Zone includes Bolivia, Peru, Ecuador, Colombia, and Venezuela; Central America includes Costa Rica, Nicaragua, Honduras, El Salvador, and Guatemala; the Caribbean includes Guyana, Surinam, Jamaica, Haiti, Barbados, Grenada, and Trinidad Tobago
b. 1959 data for Argentina, Chile, and Paraguay
c. 1971 data for Paraguay
d. 1973 data for Chile; the figure for Paraguay was estimated at 37
e. 1959 data
f. 1967 data
g. 1959 data for Bolivia, Ecuador, and Peru
h. 1979 data for Colombia
i. 1959 data for Honduras and Nicaragua; the figure for Guatemala was estimated at 20
j. 1966 data for El Salvador and Guatemala
k. 1971 data for Honduras, Nicaragua, and Panama, and 1972 data for Guatemala
l. 1973 data for El Salvador; figures for Costa Rica and Guatemala were estimated at 64 and 58, respectively
m. 1966 data
n. 1971 data
o. 1971 data for Trinidad Tobago
p. 1978 data for Trinidad Tobago
q. Estimated data

technical and financial aid is another indication of the institutes' financial problems during the 1970s.[8] Between 1960 and 1978, three of these programs—in Colombia's ICA, Argentina's INTA, and the Agrarian University of Peru—invested more than US$27 million, 45% of which was from external sources.

The evolution and importance of these programs is reflected in the number of students who initiated postgraduate studies each year (Table 5). Its growth was uninterrupted until the end of the 1960s and the beginning of the 1970s and then dropped off.[9]

In many cases, as the programs grew, the rate of personnel turnover increased and, particularly at the postgraduate level, there was a net decrease in total human resources dedicated to research and transfer of technology.

Thus, for 1975/1978, postgraduate personnel at Uruguay's CIAAB diminished 32%, at Argentina's INTA it went down 15%, and at Peru's La Molina Agrarian University it decreased 20%. Although Colombia's ICA maintained its personnel volume thanks to an active training program (Table 5), its virtual stagnation since 1978 has made things difficult (Trigo *et al.*, Chapter 4). In contrast with these situations, during the 1970s there was uninterrupted growth in the budget and number of researchers at other institutions such as Mexico's INIA and Brazil's EMBRAPA.

Reflections on New Research Conditions in the Public Sector

Problem Description

The public sector plays the dominant role in the agricultural research model although in many countries, especially the more developed ones, various types of private sector organizations are included. The public sector's performance has been notably successful and to a great extent explains the modernization of Latin American agriculture in the last two decades, thus completely justifying the creation and consolidation of the institutes. However, nearly three decades after the first national research institute was founded, the need for organizational change can be argued; Latin America's new agricultural conditions and the changing demands of scientific and technical development dictate continued adjustment.

Without intending to make a restrictive and exhaustive enumeration of these new conditions, nor implying that they are important in all countries of the continent, we will describe seven types of problems that are representative of the institutional situation in Latin America.

Agricultural Modernization and Private Sector Development

The creation and development of national research institutes as part of the public sector reflect a practical reality: most countries had weak research structures and the State appeared as the only way to generate the necessary

8 This same situation exists since 1973 in EMBRAPA, where the master's training program absorbs a large proportion of external resources.

9 For a detailed analysis of these processes, see Trigo *et al.*, Chapters 4, 5, and 6.

Table 4. Latin America and the Caribbean: annual variations in budget allocations to agricultural research, 1970/1980

	1971/1970	1972/1971	1973/1972	1974/1973	1975/1974	1976/1975	1977/1976	1978/1977	1979/1978	1980/1979
Northern Zone										
Costa Rica	2.91	1.06	0.64	0.76	1.27	1.11	1.10	0.95	1.21	0.97
El Salvador	1.21	1.17	1.26	1.12	0.97	1.80	0.90	1.24	0.62	0.88
Mexico	1.36	1.57	1.66	1.07	1.48	1.15	0.83	2.70	1.13	1.13
Nicaragua	1.04	1.03	0.83	1.06	1.15	1.08	1.10	0.84	1.08	1.07
Guatemala	–	–	0.82	1.47	1.02	0.96	1.16	1.06	1.20	1.02
Panama	1.22	1.18	0.97	0.97	0.76	0.70	1.16	1.02	1.69	0.95
Caribbean Zone										
Barbados	1.07	0.87	0.86	0.89	0.88	0.98	1.00	1.16	1.35	0.88
Jamaica	5.57	1.06	1.54	1.08	0.96	1.03	0.88	0.71	0.60	1.09
Guyana	–	–	–	0.93	1.36	0.71	0.35	–	–	–
Andean Zone										
Bolivia	1.01	0.80	1.02	1.02	0.95	0.09	1.75	1.12	0.91	0.87
Colombia	1.14	0.98	1.01	0.92	1.01	1.05	0.86	1.26	0.92	0.94
Ecuador	1.33	1.30	1.09	0.92	1.02	1.02	1.01	0.82	1.13	0.80
Peru	0.77	1.06	1.07	0.96	1.39	0.91	0.56	0.89	0.92	0.92
Venezuela	–	–	–	–	–	–	1.13	1.03	0.85	1.16
Southern Zone										
Argentina	0.84	1.10	1.25	1.20	0.79	0.94	1.02	1.05	0.99	1.08
Brazil	–	–	1.21	–	–	–	1.02	1.06	1.25	1.00
Chile	1.11	1.02	0.57	1.07	0.91	1.27	0.99	0.10	1.03	1.03
Paraguay	–	1.11	–	–	–	–	–	0.99	1.04	2.06
Uruguay	1.07	1.07	1.23	1.11	1.25	0.78	1.16	0.88	1.32	1.06

Table 5. Evolution of postgraduate training in national programs

Year	New students		
	INTA (Argentina)	ICA (Colombia)	UNA (Peru)
1960[a]	7	5	33
1961	17	9	7
1962	9	17	11
1963	18	14	17
1964	23	10	19
1965	15	11	15
1966	22	22	13
1967	34	24	27
1968	28	35	24
1969	23	40	16
1970	21	51	20
1971	39	37	10
1972	24	110	10
1973	24	96	11
1974	4	57	13
1975	1	53	7
1976	2	28	6
1977	1	7	1
1978	5	4	–
1979	13	–	–
1980	7	–	–
1981	1	–	–
1982	14	–	–
1983	1	–	–
1984	2	–	–
Total	355	630	260

Source: Trigo, Piñeiro, and Ardila

[a] Figures for 1960 include students for 1960 and previous years

organization and financing. This situation was due to the private sector's limited access to the benefits derived from research, given the predominance of agronomic technologies and the embryonic state of industrial development. This basic characteristic of agricultural technology as public property generated by the State has been changing in recent years as a result of the modernization process itself.

From a historical point of view, the first fundamental change is commercial agriculture's rapid mechanization. This displaced the agricultural labor force, modified the production process, and facilitated land expansion and the use of more productive techniques.

The second and perhaps more important change was the increased use in the production process of technological inputs (seeds, fertilizers, etc.), which are now the main instruments of technological change. These inputs allow private appropriation of the benefits derived from technology. Consequently, they also prompt the emergence of new social actors that actively participate in the development of technology and, fundamentally, in its extension (and sale) to agricultural producers.

Other very different kinds of private institutions, such as farmer associations, also took on a more important role in the process of industrializing agricultural technology.

Thus the institutional model takes on distinctive traits in many countries of the region and becomes far more complex than the original national research institute model when it was virtually the sole research and technology extension agent. Private sector participation in the innovative process is manifested in a variety of institutional and economic organizations, which in turn affect specific research objectives. Though the private sector operates in an unlimited number of ways, we will describe four in order to analyze its role in the innovative process (Table 6).

The first of these is the big oligopoly which controls processing or marketing in food-farm complexes and whose control depends on technology.[10] A classic example is the broiler industry, where the main companies control the supply of chicks and the marketing of the final product. In this case, technology is a key factor in corporate competition as well as in the subordination of economic actors within the complex.

The second—and quantitively most important—form of participation is the private production of technological inputs; the majority of these are industrially produced and therefore the result of research done outside the agricultural sector. The production and distribution of these inputs are carried out by private companies with important ties to the great transnational corporations. The connection with the transnational sector has been accomplished through the purchase of national companies which then become subsidiaries of the transnational corporations. These subsidiaries generally specialize in one or more inputs (or capital goods), producing farm machinery or germplasm for example, though their transnational owners are diversified corporate conglomerates.

Research, whether basic or oriented toward the generation of technology, in certain cases has considerable financial

10 A food-farm complex is defined as the set of economic functions which includes production, processing, and distribution of one or more similar products.

Table 6. Institutional components of a system for technology generation and transfer

Types of institutions
1. Public sector organizations
a. National institute of agricultural technology
b. Research departments or institutions in province and state governments
c. National institutions that focus on one product
d. Universities
e. Other public sector institutes
2. Private sector organizations
a. Processing and marketing oligopolies (agroindustrial corporations)
b. Technological input manufacturers
1. Seed producers and breeders
2. Chemicals
3. Fertilizers
4. Machinery
5. Veterinary products
6. Ranches that breed fighting bulls and those that raise purebred horses
c. Agricultural producers
1. Large corporations
2. Guilds
3. Producer associations
i) CREA, CETA, etc.
ii) Technical assistance cooperatives
d. Foundations

support. The private sector allocates more financial resources to the generation of technology in farm machinery and agrochemicals than does the public sector. This subsector is a typical case of private appropriation of benefits and conversion of technology into merchandise.

The third type of private organization—with a variety of legal formats and objectives—is directly connected to the farm production sector; it might be a lone corporation of great size or farmer associations that do research and/or technology transfer.

Finally, a fourth type of private organization is the foundation that has no specific connection with the production system and is not an organized association of producers. Its creation is generally due to individuals or institutions with philanthropic interests, or responds to special circumstances.

The increase in the number of institutions that participate in research and technology transfer activities presents new problems. The first of these concerns the need to establish operative mechanisms that maximize the possibilities of linking the public, semi-public, and private components of the system. The second is that, because of the diverse organizations, it is necessary to develop the ability to coordinate the activities of the system. Both problems will be considered in the next section.

Development of Technology and Basic Science

Another 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.

Institutional Capacity for Creating Technology Policies

The model for the national research institutes was partially based on the CEPAL model developed at the end of the 1960s. Without going into the general characteristics of this model nor its influence on institutional development in Latin America, we would like to single out an important element: the State is a vital factor in the transformation of society in general and the agricultural sector in particular. Hence, the State needed a powerful public sector within which the institutes could develop and transfer technology, while similar institutes carried out other types of agricultural activities.

This plan was based on two fundamental ideas. The first was linked to the then correct assessment of the weak national business sector, the technological underdevelopment of agricultural production, and the supposed resistance of many agrarian sectors to technological modernization.

The second idea was the concept of the State as representative of general social interests and, consequently, as the agent responsible for defining measures that promote economic and social development.

These ideas suggested an organizational model in which the ministries or departments of agriculture had the power to establish agricultural policies (that include technology) to be carried out by decentralized institutes and coordinated by the ministries as normative government organizations.

In our opinion, the ministries' capacity to fix and coordinate agricultural policy did not develop adequately in most countries. Since the institutes lacked clear and precise research priority directives, they had to include this role in their own structures. However, their organizational structure was inadequate for this purpose and the ensuing political discussions about priority definition and fund allocation generated internal tensions.

On the other hand, this function is much more important and difficult because of the recent expansion of the private sector and the increasingly complex nature of technology for agricultural production. Two elements should be singled out. First, the emergence of a private sector linked to the transnational industrial sector creates a new situation. Elements previously not included in agricultural policy—such as the legislation of patents or of foreign investment—must now be considered. Secondly, the State's function as both coordinator and technology generator requires precise knowledge of what all organizations are doing and a clear definition of comparative advantages in order to concentrate activities in higher priority areas.

Participation of the Users of Technology

The CEPAL model had another corollary regarding the organization of research institutions: they were to be closely tied to the public sector, run by representatives of the State as part of a national policy aimed at transforming and modernizing production, including that of rural businessmen. Consequently, these would participate only in a limited way in the administration of the institutions. This model was very different from the institutions that had inspired the existing organizational model.

In the federalized system of the U.S. Land Grant Colleges and, to a certain degree, in the French model, operative decentralization and greater regional product specialization make possible a strong sociopolitical link with the producers of each region. This link is translated into a specific social practice: producers have a say in the definition of activities and in the corresponding allocation of funds. This is not a secondary feature, but a fundamental component of the model, and does not depend on incidentals, nor on specific production structures; as a result, the producers' interests are tied directly to the survival of the organization as a whole. This local participation and formal involvement in the fixing of priorities and fund allocation have not been present in most national institutes in Latin America.

It is possible that after three decades of profound agrarian changes, the model—probably correct when it was designed—will have to be reassessed in terms of users' participation in the government of technological institutions. The first argument in favor of more user participation is linked to certain specific technological elements and to the research and extension institutes. In other institutions of the agricultural sector—such as marketing or colonizing institutions—it is possible to argue that producer participation in administrating the institution gives them a clear advantage over other sectors of society that also have an interest in these institutions. In technological institutions, this argument does not seem as important and is countered by clear advantages. The institutes are more efficient if the users can clearly express their technological needs and look upon the institute as their own, rather than as a government agency which sometimes applies agrarian policies that are often perceived as adverse to agricultural interests.

Bureaucratization and Administrative Control of the Public Sector

Research institutions were created with the clear intention of giving agricultural research a certain degree of administrative and technical independence from the central power. However, its present performance suggests that in most cases this independence does not allow the necessary administrative agility and an environment favorable to scientific creativity.[11]

This situation is the result of two interrelated processes. The first is the increasing bureaucratization and centralization of the public sector in a number of Latin American countries, especially during the 1970s. The public sector's legal and administrative complexity and the high degree of centralization in decision-making

[11] A survey of technical personnel who had left positions in research organizations in three countries of the continent indicated as one of the main reasons for their departure, the lack of adequate working conditions (see Trigo *et al.*).

affects this process. Institutional policy regarding salary levels, working hours, foreign travel restrictions, etc., is affected. These policies are in accordance with public administration criteria aimed at controlling expenses and personnel. They are particularly disadvantageous to research institutions which have their own special needs.

The second element is partially internal: the institutes' failure to establish agricultural policies that clearly set research priorities and guidelines for the definition of institutional policy has created the impression that they follow their own criteria and disregard official policy. In certain cases, this impression provokes a natural and inevitable response: the central power tries to control the institution through administrative means and introduces innumerable steps for decision and control that further bureaucratize the administrative process.

This situation poses a serious problem for research institutes because of their large size, extensive geographical range, and the diverse problems included in their mandate. As a result, decisions are often made unrealistically and are based on deficient information; in addition, they subject scientists to a system that is incompatible with research activities.

Financial Resources and Stability

Agricultural research is usually financed by public funds which are allocated from annual national budgets.[12] The principal aspects of this financial mechanism have been: a) the funds originate from general taxes, which means that agricultural research has to compete directly with all public sector activities, and b) the allocation of funds is generally made for the institution as a whole without considering program distribution, which is then done within the research organizations.

Beyond this overall scheme, there are certain important variations in sources and ways of obtaining and spending funds. The most significant examples are: INTA in Argentina which, up to 1981 and after May 1984, gets its funds from a tax levied on agricultural exports. Some para-state product organizations, such as the Economic Recovery Commission for Cocoa Bean Research (CEPLAC) in Brazil and the National Coffee Growers' Federation (FEDERACAFE) in Colombia, which carry out cocoa and coffee research respectively, obtain their funds from export tariffs on these products. Other examples that are considered special cases can be added to these: Colombia's Sugar Cane Research Center (CENICANA) is financed by a formula based on sugar exports and price differentials between domestic and foreign prices of sugar.[13]

An alternative scheme is the one that INIA in Chile has recently started using, which formally combines two types of financing: overall institutional financing and specific project financing. Their scheme provides basic funds for the maintenance of personnel rosters and includes certain operational costs to be

12 It has frequently been suggested that this financing mechanism is one of the determining factors in the budgetary instability mentioned in previous paragaphs.

13 These schemes for overall institutional financing are complemented by specific sources, such as those received by ICA through the Fifth Law of 1974. The specific programs that the Rice Federation of Colombia conducts with the brewers' industry, the pastureland research programs that Ecuador's INIAP conducts with the support of the Cattle Farmers' Association, etc., are other examples.

covered in the traditional manner by national budget allocations; remaining operations are financed by interested parties via contracts and agreements on specific research projects. This formal mechanism for mixed public and private financing is a meaningful innovation because of what it implies for the public sector role in the research process, and because of its impact on administrative aspects of research.

It is important to note that although alternate models exist, all the national research institutes, with the exception of Argentina's INTA, get the bulk of their financing from general revenues. This type of financing and the fact that research investment usually has low political priority (because its benefits are long-term and distributed among various social sectors) have resulted in considerable instability of budget allocations to agricultural research. During the 1970s, some countries registered annual variations of more than 100% in their budgets (Table 4). This instability is particularly harmful to research which by nature requires stable, long-term financing and in which instability means the possible irrecuperable loss of vegetable materials or agronomic information.

Elements for a New Institutional Model

The new situations and problems described briefly in the previous section suggest elements that could serve as a base for the institutional model which is best suited to current Latin American agricultural conditions and to the specific needs of scientific development. These elements are:

a) Administrative and financial independence necessary to guarantee financial stability and working conditions that promote scientific creativity. In Latin America this principle probably requires that research institutes have a legal framework giving them sufficient economic independence from the central powers. This demands normative mechanisms to ensure that research priorities are included in general government policies (in order to guarantee administrative independence), in the definition of institutional policy, and in financial sources.

b) An administrative process for the formulation of technological policy. We have already mentioned the importance of technological policy as the normative framework for research. The formulation of such a policy is highly political and must therefore be closely linked to the political powers. Given the special characteristics of scientific and technological activity, the scientific community and the users of technology should participate in formulating this policy.

The organizational mechanism most suitable for this task would seem to be a council for technological policy, dependent on the executive power, that includes the participation of the relevant social sectors and of the scientific community, but without direct responsibilities in research and extension activities resulting from the policy. The principal means of implementing technological policy should be financial; to this end, the council could manage a fund for financing national research programs which would be developed within the context of the general priorities defined by the council.

c) A certain critical mass of human and financial resources for the specialization needed to achieve in-depth thinking and synergic effects that result from discussing diverse methodological perspectives. However, research also requires a flexible and agile administrative system whose authority derives from scientific leadership, not from formal administrative hierarchies. It would seem more possible to achieve these conditions in institutions that are not too large and that have a certain degree of specialization and a clear, precise relationship with technology recipients. To fulfill these needs, the research system could be made up of (by subject or region) a number of independent operative units with limited, specific mandates.

d) Linkage to the recipients of technology. We have argued the need to establish institutional mechanisms that facilitate linking researcl. rs to the recipients of technology. This refers mainly, but not exclusively, to the agrarian production system. It is important that institutions dedicated to more basic research be linked to the users of the scientific knowledge they generate (generally, other research institutions dedicated to technology development). Thus the administration of the operative units should consider linking organizations to the principal users of the institutional product.

e) Organic ties with the international scientific system. It is a well-known fact that research in less developed countries depends on scientific knowledge generated in industrialized countries. In spite of this clear recognition of the problem, however, it has been generally thought that knowledge can be transferred through traditional mechanisms of scientific exchange, such as publications, international conferences, and the like. Though useful and important, these mechanisms seem inadequate as technology becomes increasingly complex, as technology development becomes a partially private sector activity, and as the science-generating centers multiply. The industrial sector's experience in the international transfer of technology, though not generally very successful, could contribute certain important lessons.

These five organizing principles illustrate the modifications that could be included in the current organization of agricultural research institutes. Obviously, the specific nature of the modifications, especially on how to link the institutes to the production sector and the mechanisms for devising technological policy, requires a careful analysis and solutions appropriate to each country.

National Programs and Their Ties to International Centers

International centers have had a major impact on national programs and, through them, on the agriculture of developing countries. It is therefore important to analyze possible trends in the activities of the centers, their comparative advantages, and the type of links that the national programs can develop with them to achieve maximum productivity.

The first international research centers were created with a fundamental mandate to improve some of the most valuable crops in the world. The basic idea was that the centers, by concentrating a group of highly qualified researchers as well as adequate funds, could have a significant impact on the yield and

general productivity of these crops. This function was projected to be medium-term and to last until the national programs could develop enough to carry on these activities.

More than 20 years after the creation of the first center, there is a consensus that international centers should remain as permanent institutions, complementary to the national programs, possibly varying their role as the national programs develop.

Some centers, particularly those founded in the 1970s, have received very broad mandates which are only partially defined in terms of regional problems; nevertheless, it appears that center effectiveness is linked to clearly defined mandates, which are restricted to the improvement of a few species of worldwide importance. These are tasks for which their organizational structure is particularly well adapted.[14] Hence it is reasonable to expect that most centers will evolve toward defined programs for the improvement of certain crops. In any case, it is not necessary to go deeper into discussion here, as the three centers headquartered in Latin America have mandates adapted to this organizational scheme.

It is important to remember that the success of international centers in improving crop varieties is based on four key elements:

a) The concentration of an interdisciplinary team of scientists (with adequate funds and operative flexibility) on a restricted and interrelated series of research problems.

b) The capacity to easily and quickly collect genetic variability on an international level.

c) The possibility of selecting genetic material collected and/or created by cross-breeding in a great variety of ecological conditions.

d) The possibility of achieving two generations of germplasm in one year by working simultaneously in the two hemispheres.

National programs cannot adopt some of the characteristic elements of international centers; for this reason, the centers concentrate their attention on the improvement of widely adaptable germplasm while the countries select germplasm for specific ecological conditions and take the process through to seed production.

In recent years, certain Latin American countries have experienced very rapid development of the private seed-producing sector, especially of those species in which hybrids are common. This sector has partly displaced the public sector in certain controlled areas of improvement and seed production.[15] Two new elements confirm the possibility that the private sector may extend its coverage to self-pollinating varieties such as wheat. First, the adoption by a number of countries of legislation that provides greater protection to the genetic material of these species and, secondly, the possible introduction of commercial

14 For a discussion of this subject, see Piñeiro, TAC, 1984.

15 It is interesting to note that private sector development, which is largely transnational, has depended on its capacity to reproduce the conditions that the comparative advantages of the international centers generate.

hybrids. Additionally, biotechnological progress could generalize the use of sophisticated techniques which may revolutionize the organization of current procedures.

It is important to note that new perspectives in autogamous species as well as biotechnological development create possibilities for the private appropriation of research benefits. As a result, there is greater interest in the private sector, which is already making substantial investments in this area.

The development of the transnational private sector and the growing dependence of applied research on basic science define new conditions for international centers and their relationship to national programs. Much of the basic information which is now generated by universities and other public sector organizations in industrialized countries—and therefore available to the centers and to national programs—could in the future become secrets protected by patents and/or commercial practices. Then too, there is the national programs' difficulty in being informed and having access to the scientific advances of the rest of the world.

This suggests that the international centers might play a fundamental role in the national programs' scientific progress, that is, they could serve as link and channel in the transfer of scientific advances. Their role would be similar to that of transnational parent companies dealing with their affiliates in developing countries. In this manner, the centers would contribute to the development of national capacity in the improvement and production of seed and would provide an alternative to total dependence on the transnational sector.

Final Reflections: Consolidation of National Research and the Need for External Financing

In previous sections we have emphasized the need to initiate in Latin America the consolidation and readaptation of national agricultural research programs to the new conditions and demands of scientific development. This is necessary not only to solve the problems of food and agricultural production, it is also central to the socioeconomic development of the countries of the continent. However, it is not possible without considerable foreign resources, especially now that there is a tense financial situation in most countries due to the foreign debt.

The burden of the debt and the resulting devaluations in a number of the countries of the region have had a fundamental effect on the financing of research organizations. Table 7 shows the budgets of the national research institutes in three countries which allocate ample funds to research and have heavy international debts.[16] This trend probably illustrates the general situation currently being experienced

16 The purchasing power of the budget has not necessarily diminished proportionately because of the marked devaluations of the dollar in the three countries. In Argentina's INTA, the return to budget autonomy in 1984 means recovering its independence of the foreign debt problem in the future.

by the majority of Latin American countries. Unfortunately, the urgent need to readapt and consolidate research organizations coincides with the most serious budget crisis in recent history. This situation points up the importance of current foreign aid programs[17] as well as the opportunity for new and ambitious institutional development projects in the agricultural research area, which would permit Latin American countries to modernize and consolidate their scientific and technical capacity.

Acknowledgement

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Table 7. Resources received by INTA, Argentina, EMBRAPA, Brazil, and INIA, Chile, 1978/1983 (in 1983 US dollars)

	INTA	EMBRAPA	INIA
1978	137,004	162,576,424	11,048,589
1979	150,477	177,307,107	11,436,915
1980	134,147	171,397,186	12,827,834
1981	113,228	180,541,903	15,762,233
1982	41,371	235,487,273	10,707,131
1983	45,561	129,389,279	8,733,865

Source: Data were given in local currency and converted to US dollars by the authors, who brought them up to date according to the US wholesale price index. The authors thank J.C. Borelli, Antonio da Oliveira, and E. Madrid for the information they supplied.

17 The Inter-American Development Bank (IDB), as well as the World Bank, have active loan and technical assistance programs supporting agricultural research activities at the national level. Between 1971 and 1980, IDB granted 13 loans totaling US$137.9 million to eight countries as well as US$25.0 million in nonrepayable technical cooperation distributed among 20 projects in 13 countries. The World Bank has granted two loans for US$96.0 million. Among the bilateral aid programs, the main one is the American program which in 1980 had 25 projects with close to US$70.0 million committed until 1985.

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Comment

Norman E. Borlaug*

Martin Piñeiro and Eduardo Trigo presented a complete overview that illustrates the emergence and evolution of agricultural research institutions in Latin America and the Caribbean. I congratulate them for an excellent paper that has caused us to think deeply about the problems and opportunities that we face.

I do not intend to make any new additions to Piñeiro and Trigo's presentation; rather, I will underline some of the aspects they pointed out, particularly in regard to maintaining the viability and efficiency of research institutions. My comments are based on 40 years' experience working in these and other parts of the developing world. Needless to say, over so a long a period I have witnessed the development of several of the organizations represented here today.

Forty years ago, it was indeed difficult to imagine institutions the size of Brazil's EMBRAPA, Mexico's INIA, Argentina's INTA, and Colombia's ICA, to mention a few. At that time, most countries lacked established research programs; others had modest programs with scant physical and human resources.

The situation has changed in the last few decades and, just as Piñeiro and Trigo indicate, the development of agricultural research institutions in Latin America has been remarkable, as well as the amount of funds allotted to them. The authors, however, point out that, with the exception of a few institutions, research development has fluctuated greatly, as if its viability were fragile or uncertain.

Thinking about this reminds me of what F.F. Hill, former Dean of the School of Agronomy at Cornell University and Vice-President of the Ford Foundation, told me years ago: "Research institutions, like empires and fashions, go through a cycle: they are born, they grow, they branch out. Then they decline and wither away." Above all, we must not forget that institutions are built by man and that we have to make sure they serve society effectively.

I was saying that because of the uneven and sometimes difficult evolution of research institutions in Latin America, I am concerned about their permanent vigor and efficacy. How can a research institute ensure its viability and effectiveness? How can we avoid the decline of men, approaches, and programs? After reviewing factors that affect these institutions adversely, I can think of several answers.

Let's not overspecialize

Young people who go to the United States or to Europe for postgraduate training frequently acquire the "academic counselor syndrome" and an excessive inclination to specialize in narrow fields on which they write detailed theses. On returning to their own countries, they become frustrated because there are no facilities or equipment for applying what they have learned. As a result, national institutions lose human resources that were costly to them. Let's make sure that our scientists remain sensitive to the real problems that plague production and research fund productivity, without losing their scientific curiosity or creativity.

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Let's set up work teams with defined programs and goals

It is not easy to coordinate individual efforts, especially if we don't have defined programs and goals. Many times I have observed brilliant specialists working alone, each hiding behind his own tree and unable to see the forest. I have watched geneticists, pathologists, soil specialists, entomologists, physiologists, and economists, who, in spite of working on the same program and crop, do not share information. Individuals keep to their own line of research, without a director to bring them together. These scientists can work on a given problem for 20 years without reaching definite conclusions or recommendations that will help to improve production. In this way, institutions become useless organisms.

One way to avoid wasted efforts and institutional decay is having directors who bring together and coordinate individual efforts in a collective endeavor aimed at achieving concrete results. They must be sensitive to the problems of agrarian policy and, at the same time, convince political leaders of desirable changes in prices, services, input supply, etc. In other words, we need charismatic leaders who can see the forest without getting lost among the trees.

Let's not become bureaucratic

As research institutions grow and develop, they become more and more bureaucratic. The amount of internal red-tape multiplies constantly, and the number of personnel required to handle thousands of memoranda, regulations, reports, administrative documents, etc., increases. What is worse, when institutions come under the Ministry of Agriculture, they become absorbed by the procedures they are obliged to follow and spend hundreds of man-hours complying with bureaucratic orders. Many able researchers who have been promoted to administrative positions (instead of continuing their field work) take part in these procedures. A bureaucratic institution does not promote advances in research.

Let's give young people a chance

In a bureaucratic institution where promotions are granted according to seniority, the directing staff are not necessarily the most able people. The result is a gerontocracy that denies opportunities to young people, who consequently become frustrated and leave. An institution without highly motivated, vigorous young people is doomed to decay.

Institutes should be linked to the users of technology

Agricultural research institutions exist to serve a country's farmers; however, farmers usually do not participate in planning, carrying out, and funding research projects. Farmer participation no doubt makes programs more dynamic and orients their activities towards solving real problems. A positive example of this approach is the Association for Agricultural Research and Experimentation in the State of Sonora in Mexico, a group which supports INIA's research efforts in the region through funding and resources.

Let's use new scientific methods and technologies cautiously

There are no substitutes for man's creativity, imagination, talent, and dedication. There are no miraculous solutions to agricultural problems—not electronic microscopes, nor radiation techniques that induce mutations, nor large and small computers, nor biotechnology. We should use available and appropriate solutions wisely, without acquiring complex and costly machines that are not very useful and

that will later become broken-down relics, reminders of our folly. Let's not get carried away by new technologies without first assessing our real needs, possibilities, and opportunities.

Let's not become complacent

Many of the institutes represented here today have made important contributions to their countries' agricultural production, and for this they rightly feel great pride and satisfaction. Nonetheless, it would be a mistake to become complacent and rest on our laurels. Winning one battle does not mean we've won the war, and there are still many problems to solve; farmers in Latin America and the Caribbean expect much more from us. Let us work with them.

In conclusion, I wish to point out that my comments are also meant for international and regional centers, since they, too, run the risks that I have mentioned.

Emilio Madrid*

First of all, I would like to congratulate Drs. Piñeiro and Trigo for an excellent analysis of the situation, and for pointing out the similarities in the evolution of agricultural research activities in Latin America. My comments will be specific and will follow the same order as the original presentation.

National Programs

In the section that focuses on the national research institution as the dominant organizational model, there is a paragraph on how research is progressively becoming less important at universities and agricultural schools, as opposed to its growing importance at institutions that are under the ministries of agriculture. I agree wholeheartedly with this observation and would like to add that the reason for it is that most universities have concentrated on training professionals to solve immediate technical problems, not on creating research scientists. Many universities still have not changed this perspective. Therefore I think this aspect merits a more profound assessment; perhaps it should be included in the basic elements for designing a new institutional model for agriculture in Latin America.

INIA in Chile has followed the general pattern of a decentralized and autonomous public sector organization that integrates research and transfer activities as its operational base. However, over the years, there have been varying degrees and modes of technology transfer activities. This cyclic process, which originated within the Institute itself, links it to the Ministry of Agriculture extension service through production specialists trained at INIA. Although the process had impressive results, changes in government leaders and policies rendered it highly unstable; this ultimately brought about the disappearance of the Department of Agricultural Extension of the Ministry of Agriculture in 1980, as well as the reinforcement of transfer activities at INIA (with its own unique style) since 1982.

Reflections on New Research Conditions in the Public Sector

Agricultural Modernization and Private Sector Development

The authors correctly state that "from a historical point of view, the first

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fundamental change is commercial agriculture's rapid mechanization". In my opinion, a special mention of "small farmer" agriculture must be added. The small farmer took part in what we could call the motorization process, for he, too, seeks better working conditions and efficiency. Nonetheless, he has not had the full advantage of technological inputs, so that today many of our institutions are dedicated to creating or adapting adequate technologies, especially animal-powered farm machinery which is efficient and compatible with the small farmer's economic possibilities.

"The increased use in the production process of technological inputs which are now the main instruments of technological change" is indicated as the second, and perhaps more notable, change. This is true, but as for their allowing "private appropriation of the benefits derived from technology", I think the situation is different in each country, and this statement could only apply to countries that have industrial sectors that develop or manufacture inputs (pesticides, fertilizers, machinery, etc.) This is not the case in Chile, where seeds, especially hybrid ones, and certain animal health inputs, which are manufactured domestically, seem to be more important.

As for private sector participation in the creative process, specifically, "the big oligopoly which controls processing or marketing in food-farm complexes", in Chile these complexes show a growing interest in the technological aspects. For example, oil seed processors, breweries, potato chip manufacturers, and alcoholic beverage processors are contracting more and more research from INIA. I think there are at least four reasons for this:

a) Research confers prestige, since technically it is backed by a reknowned institution.

b) Business firms can directly affect research orientation.

c) Business firms appropriate results, especially the physical ones, since the possession of scientific knowledge or technologies is short-term. What the firm usually exploits is the advantage of being the first to have certain technology during two or three years; the better the business promotes the technology, the shorter this period is.

d) Although national institutes are not considered consultants, they fill this role when they analyze and solve specific problems for business firms.

Our experience at INIA indicates that to carry out contract activities adequately, institutes should fulfill at least three basic requirements:

- Very efficient use of the funds given them by the business enterprise. (This has not been difficult to do at INIA because it already had organized programs.)

- Great effectiveness in producing useful results within a short period.

- Guarantee of trade secrets; this aspect can conflict with the social function of the institutes and depends on the discretion and loyalty of the researchers.

This type of agreement, called a CONTRACT, is generally made with an affiliate or subsidiary of a transnational corporation with whom we have worked on specific seed or product trials.

In Chile, private organizations linked to the agricultural producer sector do not participate very actively in research, except those that produce export commodities (especially fruits) and are concerned with product quality and appearance. Here the concept of appropriation is not as developed,

though being the first to come out with a product or technology is very important. As a result, INIA does not establish contracts with this type of private organization, as it does with transnational affiliates; it establishes shared financial relations, since the Government is interested in promoting these products. This type of accord is called an AGREEMENT. All of these transactions are possible because INIA is legally a "private corporation".

The following operative aspects are undoubtedly necessary for coordinating public, semipublic, and private sector components of the research and transfer system for agricultural technology: a) the State must have the power to establish clear, long-term agricultural policies, which, on the market, result in positive or negative reactions to generation and transfer, and b) national institutions should be flexible in adapting to technology demands.

In INIA's experience, private sector participation in funding has never been more than 3 or 5% of what the State contributes; nevertheless, the strategic value of its contribution is greater because it projects a favorable image of the private sector.

Basic Science and Technology Development

I fully agree with the authors' opinion that "the institutes were, at least in the spirit of the law of their creation, restricted as to basic research activities".

It is also true that because of their nature, the institutes developed "quite independently of the rest of the national scientific and technical system". No doubt resource availability is not balanced, and, in Chile's case, the amount of basic research done on-farm is very limited because the universities have concentrated on training professionals. In order to attract funds, they compete in the field of technological research, while neglecting the generation of knowledge that basic research produces.

Because the weaknesses of the national scientific system have "limited the institution's efficiency in its specific task of generating technology", the system evidently needs strengthening and economic support. It would be ideal if the institutes had funds for promoting the development of scientific knowledge, especially at the universities.

All this confirms that developing countries run the risk of not always having access to basic information. The solution would be to strengthen the whole national research and transfer system with a clear sense of complementing existing national resources. This eliminates, at least in Chile's case, the possibility of the basic science infrastructure becoming a part of the institutes themselves.

Institutional Capacity for Creating Technology Policies

I think the core of the problem is expressed in one of the paragraphs that apply fully to Chile: "The ministries' capacity to establish and coordinate agricultural policies did not develop adequately in most countries. Since the institutes lacked clear and precise research priority directives, they had to include this role in their own structures. However, their organizational structure was inadequate for this purpose and the ensuing political discussions about priority definition and fund allocation generated internal tensions."

Participation of the Users of Technology

Although generally I agree with the authors' opinions, it does not seem logical to base farmer participation on the American and French models. These cultures are very different from

the Chilean farmer's society; he has been more concerned with tariff policies, prices, subsidies, land tenure, credit, etc., than with technology. Granting these farmers a vote in the definition of activities and in fund allocation carries the risk of introducing their problems in the institution. Therefore, traits such as a recognized sense of the public good, high objectivity, and moral as well as technical authority over producers, researchers, and extension agents should be taken into account in selecting the people who will participate in the process.

At INIA there is this type of participation, and the five-member Board of Directors includes two farmers.

Bureaucratization and Administrative Control of the Public Sector

I am totally in agreement with the authors on this point. INIA felt the lack of an agricultural policy to define research priorities; the official sector thought that the Institute was being run according to its own criteria, and [illegible] tried to control it through [illegible]istrative means. However, INIA successfully solved the problem thanks to strong but flexible national programs (which generally coincided with Government priorities) and to its capacity for transferring useful technologies to different clienteles within very brief periods. This capacity was the result of major changes in technology transfer policies. Another reason for INIA's success was that it was able to show the authorities that efficient research was being carried on by an excellent team of technicians and scientists.

Financial Resources and Stability

I only wish to point out that where the authors say "an alternative scheme is the one that INIA in Chile has recently started using", they should have said "has recently suggested using" because the combination of overall institutional financing and specific project financing is a proposal that has been submitted to the consideration of the authorities. It is being put into effect partially, but aspects related to state support and private sector participation need to be worked out.

Elements for a New Institutional Model

Section a seems essential to me. There should be a certain degree of administrative and financial independence to guarantee economic stability and the possibility of creating work conditions that promote scientific creativity. Section b: Chile attempted to set up technology policies which were strongly linked to the political powers through establishing an Agricultural Research Board as consultant to the Ministry of Agriculture. Unfortunately, the Board soon became an administrative power and tried to control INIA by administrative means and by fund allocation. The biggest mistake was that when it was legally established, the Board was given responsability for carrying out research and technology transfer, according to policies which went into effect at the same time.

While it is true that the Board should manage a fund as the principal means of applying technology policies, it should do so in a general way, without going into specifics; if it does go into specifics, it will need an administrative infrastructure (Executive Secretariat) which could easily take on the role of the institutes.

Setting up a research system based on a number of independent operative units with defined, concrete mandates, by themes or regions, does not seem adequate for institutes of smaller countries like Chile, where agriculture

varies greatly according to regions. In these countries, there may be nationally important products that would justify the existence of national programs made up of various regional research and transfer units.

There is no doubt that transmitting scientific knowledge through scientific publications, international conferences, and other traditional means is not sufficient. Besides a basic link to the international scientific system, other activities are necessary to complement horizontal technology transfer. Hence the importance of the international centers and cooperative programs in agricultural research, such as the model established by the IICA-Southern Cone/IDB Agreement. These programs must be based on personal contact among scientists who work on the same product or discipline in different countries, and on cooperative research between two or more countries. (Both situations promote bonds that often result in friendly relations among researchers.) The programs must be medium or long-term, since our countries do not usually have the financial means to make them self-sufficient in a short time.

National Programs and Their Ties to International Centers

I fully agree with the authors and only wish to underline two aspects and add some thoughts to their statements. First, I share and emphasize the opinion that the centers must be permanent institutions that complement national programs.

Secondly, I wish to point out the importance of these centers in internationalizing the use of phytogenetic materials which have been monopolized not only by transnational corporations, but by industrialized nations as well.

Given the permanent and complementary role the international centers should play in relation to national programs, it is necessary to reflect on how much the genetic materials which the centers supply to different countries should be processed. If they are processed enough to be used directly by the farmer, that may create the risk of national research authorities deciding that complete, strong national programs are not necessary. This is not meant to criticize the centers; it merely alerts them to the need for a good assessment of current national capacities. It also points out to national research administrators the significant complementary role that these institutions must play.

Consolidation of National Research and the Need for External Financing

Here I wish to emphasized what the authors indicate: a substantial inflow of foreign funds is absolutely necessary to promote, readapt, and consolidate national programs and to implement collaborative programs. Paradoxically, financial institutions seem to be more aware of this than the authorities responsible for national economic development.

Finally, if we are to promote ambitious institutional development projects in order to consolidate our scientific and technical capacities, we must be aware of the need to strengthen the management function in our national institutions. In some cases, perhaps it would be best to give corrective training to directors and other officials who have technical and administrative responsibilities. Nevertheless, we must also begin systematically training researchers who have the ability to assume administrative responsabilities within agricultural research. I believe ISNAR has a clear-cut task in its mandate with regard to this subject.

Opportunities for Investment in Conventional Agricultural Research in Latin America

Eduardo Venezian*

Introduction

It is becoming more and more necessary to increase agricultural productivity in Latin America because of rapid population growth, improved standards of living, and progressive limitations to expanding agricultural lands. Consequently, agricultural science and technology are becoming increasingly important in relation to natural resources, since they promote economic development and are sources of wealth and well-being. Agricultural research that creates and uses scientific knowledge to generate technology is essential to the productive activities of a country.

Though the above is obvious to agricultural scientists, economists, and experts on socioeconomic development, it is less so to the governments and legislatures of developing nations. One reason for this may be that the recipients (farmers and/or consumers) of agricultural research results frequently are not aware of the value of research. Since it is carried on quietly, produces results slowly, and reaches its targets in the form of inputs or technologies that do not reveal their origin, the lack of appreciation for their social value is not surprising. Sometimes this type of research is criticized for being unproductive or useless, for being a luxury in poor countries, or for being unnecessary, since agricultural technology could be imported from industrialized nations.

Thus the investment of public funds in agricultural research is not a high priority in Latin America and fluctuates greatly over time. The private sector invests very little in research. It is important to note that the founding and strengthening of national agricultural research systems is due mainly to the influence of foreign agencies and programs; the exploitation of new opportunities depends on foreign or international support that stimulates national interest.

This paper analyzes the current state and organization of agricultural research in the region; possible study areas or topics for the next decade, within traditional patterns that the existing institutions have employed, are examined. Regional analysis, though encumbered by conceptual and informational limitations, nevertheless makes possible comparisons and generalizations that detect opportunities for investment in agricultural research both in individual countries and in regional cooperative groups.

Some Considerations on Research Investment

First of all, research is a permanent activity, for its production never ceases; what is more, in the modern world, scientific and technological research is a growing industry, and as its frontiers expand, the opportunities for applied and technological research (such as agricultural research) are broadened. The basic premise, therefore, is that

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agricultural research is suited for investment, all the more so because through it developing nations can capitalize on the generally costly technological advances of wealthy nations and international centers.

Secondly, there is much evidence that this type of research yields high social returns. Great progress has been made in estimating returns since the pioneering work by Griliches on hybrid maize in the United States. Numerous studies both in developing and developed countries show rates of return in the range of 30 to 90% annually (Evenson *et al.*, 1983); Latin America presents a similar situation (Table 1). Among these studies, Franco's work on rice is noteworthy for its *ex ante* evaluation of a research program, an example of the potential of cost/benefit methodology as applied to the allocation of research funds. This will be discussed further later on.

Although return analyses have not been done very extensively, and not on unsuccessful projects, they do indicate that well-managed research offers extraordinary opportunity for social returns. High rates of return are an indication that there is not enough investment in this type of research in Latin America. Other studies reach the same conclusion through different analytical methods (Martin and Esfandiari, 1980). In a later section we will see that research investment is very low in Latin America when compared to international figures. Once again, this reinforces the general opinion that there are good investment opportunities in this field within the region.

Thirdly, it must be acknowledged that most agricultural research in Latin America over the past three decades has focused on basic food products and related problems, while industrial crops and/or potentially exportable crops have been largely ignored. Foreign aid organizations and international research centers have emphasized this tendency because of their exclusive attention on basic crops and their influence on national research institutes.

When examining investment possibilities in national research, however, it is important to keep in mind the goal of increasing the total value of agricultural products (or agricultural income) which may be easier to reach by means of expanding non-traditional crops. This implies that the foreseeable changes in consumer patterns, brought about by increased per capita income, social distribution mechanisms, and the advantages of the international free market, must be considered. Within this broad context, the range of products and problems that could be studied in coming years is enormous, and though public sector research should not address all of them, it should not exclude them *a priori*.

Finally, regional analysis can conceal the fact that investment opportunities in research are usually selective, for they are not open to all institutions. In some cases, national institutions may not have the capacity to tackle the problem; other problems may be implicitly supranational, and others should perhaps be studied by specialized or private institutions that are sometimes non-existent. To sum it up, it is not enough just to consider research opportunities, the institutional situation should also be explicitly analyzed. For this reason, it is very important to examine the institutions that make up the research systems in Latin America.

Current State of Agricultural Research in Latin America

History—Scientific and systematic agricultural research on a national level developed in the region after World War II (Table 2). Though in the last century some countries had experiment stations or centers and before the 1940s there already were some high quality centers such as the Agronomic Institute in the State of Sao Paulo (Elgueta, 1982; Pastore, 1982; Trigo *et al.*, 1982), agricultural research did not become important until after the United States and international organizations began foreign aid programs.

The origins of agricultural research are important, for they profoundly influenced the organization, philosophy, and orientation of nearly all the research systems in the region; they also help to explain the similarities between the systems of different countries, in spite of the enormous differences in agricultural resources and other socioeconomic characteristics. The fact that in the last 20 years most research personnel (with master's or doctor's degrees) have been trained in the United States or in national graduate programs similar to those in the USA is also significant.

Latin American scientific agricultural research is still young, considering the time it takes to establish institutions.

Table 1. Studies of agricultural research profitability in Latin America

Country	Study	Product	Period	Domestic rate of return (%)
Mexico	Ardito-Barletta	Wheat	1943/1963	90
	Ardito-Barletta	Maize	1943/1963	35
	Ardito-Barletta	Crops	1943/1963	45-93
Brazil	Ayer and Schuh	Cotton	1924/1967	77-110
Peru	Hines	Maize	1954/1967	35-40
Colombia	Scobie and Posada	Rice	1957/1964	79-96
	Hertford *et al.*	Rice	1957/1972	60-82
	Hertford *et al.*	Soybean	1960/1971	79-96
	Hertford *et al.*	Wheat	1953/1973	11-12
Bolivia	Wennergren and Whitaker	Sheep	1966/1975	44.1
	Wennergren and Whitaker	Wheat	1966/1975	–47.5
Chile	Yrarrázaval *et al.*	Wheat	1949/1977	21-28
	Yrrarázaval *et al.*	Maize	1940/1977	32-33
	Franco	Rice[a]	1981/1990	14-20
	Franco	Rice[a]	1981/1990	86-105

Source: Evenson, R., P. Waggoner, and V. Ruttan, 1983; Trigo and Piñeiro, 1984; Yrarrázaval *et al.*, 1979, and Franco, 1981

[a] These two studies differ in costs considered in the program; the first includes costs prior to 1981, and the second only includes future costs

train scientific personnel, and rally public support for a field that yields intangible results slowly. Nevertheless, research institutions have been consolidated and have demonstrated their high-yield capacity, as is evident in rates of return studies of research investment in the countries of the region. I will examine the organization and performance of agricultural research in Latin America in order to establish a framework for discussing research opportunities.

National agricultural research systems (NARS)—Agricultural research should be examined in the context of a system because of the different activities it comprises and the diverse institutions that carry it out, make decisions, and share information. Although many times agricultural research does not, strictly speaking, function as a system, at least structurally it contains the elements for national agricultural research systems. The following are the institutions that make up the NARS.

a) **National agricultural research institutes**—The main element of the typical research system is a national (public sector) institute which is always the largest in program scope and funds (Table 2). The national institute model that dates from the

Table 2. Main characteristics of the national agricultural research institutes in Latin America countries

Country	Acronym	Year founded[a]	Legal status[b]: Central pub. sect.	Legal status[b]: Semiauton.	Tasks[c]: R	Tasks[c]: T	Tasks[c]: E	Tasks[c]: S	Operative regional decentralization
Argentina	INTA	1956	x		x	x	x		x
Bolivia	IBTA				x	x			
Brazil	EMBRAPA	1973[d]		x	x				x
Colombia	ICA	1962	x		x	x	x	x	x
Chile	INIA	1964		x	x	x[e]			x
Ecuador	INIAP	1961	x		x				x
Guatemala	ICTA	1973		x	x	x			x
Mexico	INIA	1961	x		x				x
Panama	IDIAP		x		x	x			x
Paraguay	DIEAF		x		x	x			
Peru	INIPA	1960[f]		?	x	x			x
Uruguay	CIAAB	1961	x		x	x			x
Venezuela	FONAIAP								

[a] This refers to the present institutions; all of them were preceded by institutions which were very different, both administratively and functionally
[b] This indicates how much the institution depends on the Ministry of Agriculture, or whether it belongs to the public sector
[c] R: Research; T: Technology transfer; E: Postgraduate education; S: Sanitary control
[d] The previous research institution, DPEA (1962), was under the Ministry
[e] Since 1982, only responsible for reaching middle and large farmers
[f] Year that SIPA was founded; it was later restructured as INIA (1978), and finally, as INIPA (1981)

early 1960s has changed many times in all the countries of the region, partly as a result of political and economic change and also because it evolved and adapted progressively in order to perform its role more adequately. Various studies have analyzed the evolution of some of these institutions in detail (Trigo, Piñeiro and Ardila, 1982; Pastore, 1982; Elgueta, 1982).

Their varying development notwithstanding, these institutions presently share certain fundamental traits:

- *Ample range of products and disciplines*—As will be discussed in a later section, national institute programs tend to cover the most important agricultural products in each country. This is true for food crops; some industrial or export crops are excluded because their research is carried out by specialized or private institutions. These programs also carry out research in support disciplines (soils, genetics, entomology, etc.) and in semiarid areas, high plateaus, "cerrados",[1] etc.

- *Administrative autonomy*—Entities that have been legally established as semiautonomous organisms or state enterprises, such as EMBRAPA in Brazil, INIA in Chile, and ICTA in Guatemala have a higher degree of independence. However, even when these institutes are part of the department or ministry of agriculture, as in Argentina (INTA) or Colombia (ICA), their organization and established relationships give them a high degree of operative independence that includes defining their own programs, as will be seen later.

- *Decentralization*—Nearly all the institutes are set up as regional or specialized centers that direct subcenters or experiment stations. They have operational autonomy within national programs; this characteristic structure is found both in large (Argentina, Brazil, and Mexico) and small countries (Guatemala and Panama), where the need for such structure is not as evident.

- *Highly trained, full-time technical personnel*—All these institutes have postgraduate, full-time personnel that are dedicated solely to the institutions; usually there are permanent training programs for technicians as well. EMBRAPA is an outstanding example of this type of training facilities, but it is also found in institutes of smaller countries. A problem that is common to nearly all institutes is the high rate of personnel turnover (Trigo, Piñeiro and Ardila, 1982).

Over time, there is greater diversity among different nations in the degree of research specialization. These changes are the result of the differences of opinion as to how to integrate research and transfer activities and decisions on the use of high quality institutions to carry out functions that technically belong to other institutions. The usual practice is to link technology transfer to research within the same institution, although institutes such as EMBRAPA in Brazil and INIA in Mexico limit themselves strictly to research (INIA in Chile just lately began carrying out limited transfer activities).

On occasions, some institutions such as ICA and INTA have assumed responsibility for postgraduate

[1] Highly leached acidic soils with toxic levels of soluble aluminum, found in large areas of Brazil.

training in agricultural science. It does not seem to be successful and now there is a tendency to delegate this activity to the universities. There is at least one case (ICA) where responsibility for plant protection and quarantine was given over to a research institution; this type of activity is incompatible with research and apparently affected ICA seriously.

There are also significant differences among the institutes of various countries as to the formal participation of farmers in research decision-making. For example, while there is much participation at all operational levels at INTA (Naumann, 1983) and limited participation at Chile's INIA, in some countries there is none at all. This seems to be changing with the introduction of on-farm research programs that involve closer interaction between researchers and farmers.

b) **Public research institutes (decentralized or specialized)**—In many countries there are public sector research institutes or centers that are dedicated to specific areas or products and are independent of the national institution. Brazil's centers or state enterprises, covering defined geographical regions, are outstanding and, among these, the research system of the State of Sao Paulo is worth mentioning because of its seniority, size, and quality.

Common practice in crop specialization is to handle forestry research separately (INIF in Mexico, CONIF in Colombia, and CONAF in Chile), as is the case sometimes in livestock research (INIP in Mexico), and frequently in important export products (CEPLAC for cocoa beans in Brazil; coffee institutes in Brazil, Colombia, and Mexico; IMPA in Mexico and Planalsucar in Brazil for sugar cane).

These institutions are generally much smaller than the national institutions and perform other functions besides research. Their degree of coordination and integration to the national system is usually variable and weak.

c) **Universities and agricultural schools**—In some countries, agricultural schools played an important role in research even before the founding of national institutes (for example, Brazil and Mexico) and, since the 1960s, their importance has increased greatly. A thorough analysis of research capacity in Latin America cannot overlook the universities, for they have established experiment stations and laboratories and have trained highly qualified professionals that work full-time. Thus agricultural research has become a permanent and intensive activity that is generally linked to postgraduate programs. There are numerous instances where production of improved varieties of different species (soybean in Vicosa, Brazil, wheat at the Catholic University of Chile, etc.) and other farming practices began at the universities.

An example of the significant role of the universities can be found in Chile (Cañas, 1981), where the four main agricultural schools had 2.4 times the number of researchers as INIA (3.0 times, if only master's and doctor's degrees are taken into account). Supposing these researchers devote only one third of their time to research, this would mean more researcher/years than at INIA. Their overall scientific output, estimated by the number of scientific publications, was 2.8 times higher than INIA's. This illustrates the universities' contribution to research, since the situation is similar in Argentina, Brazil, Mexico, and other nations.

The enormous expansion and improvement of Latin American universities in agricultural research poses a serious problem in the planning and/or coordinating of research activities at the national level. There are opportunities for division of labor and cooperation that would benefit everyone, but there is also a lack of adequate mechanisms to achieve this.

d) **Private sector research institutes**—Private research institutes or experiment stations are frequent in the region; they are usually dedicated to limited research themes (Marcano, 1982). Many of these institutes belong to farmer associations, as for example, the Chinchina Station of the Coffee Growers Federation in Colombia or the experiment station of the National Farmers' Society (SNA) in Chile. Others are financed by large national or multinational companies that have an interest in certain products (tobacco and sugar cane research in Ecuador, hybrid maize in several countries). Finally, there are some profit and non-profit private institutions that are dedicated to agricultural research, such as FUSAGRI in Venezuela (fruits and vegetables), Semilleros Baer in Chile (lupine and cereals), and IRI in Brazil (fertilizers). These institutions play a role in national research systems as private sector participants in agricultural research, a matter which should merit more attention in the future.

Expenditures in Agricultural Research

It is easier to envision the size, capacities, and restrictions of the NARS and the institutions which comprise them if one analyzes their financial resources. Available information on the subject is not very complete nor solid, but the growing interest in the finances and administration of agricultural research has encouraged experts and international organizations to look into this subject.

In the first place, comparative studies (Boyce and Evenson, 1975) indicate that, of the five main regions in the world, Latin America invested the least in agricultural research until 1974. Although since then some countries have increased their investment considerably, Latin America is undoubtedly far beneath the investment patterns of the most developed regions in the world.

Table 3 shows research expenditures per country for 1975 and the relationship between these expenditures and the gross national farm product (farm GNP). Only four countries spent more than 0.6% of the farm GNP on research, and the regional average was 0.3%. In industrialized nations it was more than 2% (Evenson, 1978). The same data for 1979 confirm the low ratio of the farm GNP that is invested in research, although in that year there was a higher regional average (0.57%) and some considerable differences between one year and the next in certain countries.

The tendency to increase this investment is demonstrated in Table 4. All countries increased their investment significantly between 1960 and 1980 and all except two increased it between 1970 and 1980, at a generally higher pace than the growth in the farm GNP. Brazil, Mexico, and Venezuela greatly increased their investment, while Argentina, Chile, and Peru show relatively small increments for the same 20-year period. After 1980, available data indicate that this tendency has been reduced, no doubt as a result of the international economic recession.

The main public sector institute always has a larger share of national research system funds and a high ratio of total expenditures in agricultural research For example, in 1977 EMBRAPA obtained approximately 50% of a total of US$204.7 million that Brazil invested in agricultural research (Sánchez and Barros, 1981); in 1976, ICA absorbed 80% of Colombia's research investment (Chaparro *et al.*, 1981), and INIA claimed over 50% of Chile's total investment. Comparable ratios must be higher in smaller nations.

Agricultural research is largely financed through allocations from the public sector budget. Some countries have tried to modify this situation, but without permanent results, except in rare cases. For example, for a few years, Argentina's INTA was funded through a farm product export tariff and Brazil's CEPLAC has been financed through a duty on cocoa beans. Chile's INIA has tried generating its own income as a "business" and succeeded in covering nearly 50% of its operating costs, but it is too early to make an

Table 3. Latin America: projections of agricultural research expenditures by countries, to 1990

Country	Research expenditures 1975	Research expenditures as % of farm GNP 1975	1979[a]	Projected expenditures 1990	Increment 1990/1975
	Thousands of US$	%	%	Thousands of US$	Annual %
Argentina	31,909	.54	.79	63,678	4.7
Bolivia	279	.09	.87	3,490	18.3
Brazil	79,267	.54	.67	159,535	4.8
Colombia	17,956	.50	.56	39,181	5.3
Costa Rica	1,550	.40	.24	4,236	6.9
Chile	5,841	1.19	.48	10,480	4.0
Ecuador	3,681	.41	.54	9,747	6.7
El Salvador	800	.18	.28	4,733	12.6
Guatemala	859	.09	.27	10,633	18.3
Haiti	55	.01	.05	4,387	33.9
Honduras	460	.15	.13	3,306	14.0
Jamaica	1,367	.58	.25	2,528	4.2
Mexico	12,980	.16	.52	86,532	13.5
Nicaragua	1,064	.34	.42	3,750	8.8
Panama	2,770	.90	.36	5,008	4.0
Paraguay	648	.12	.26	6,040	16.0
Peru	10,189	.50	.26	22,076	5.3
Uruguay	1,947	.44	.14	4,722	6.1
Venezuela	8,656	.49	.94	18,964	5.4
Total	182,278	.31	.57	463,026	6.4

Source: Adapted from Oram, P. *et al.*, 1979

[1] The figures in this column were taken from Trigo and Piñeiro, 1984

assessment of the results. In all these examples it would be interesting to analyze the connection between the manner of funding, total research investment, and its distribution by product or project; unfortunately, there is no information on which to examine this subject.

Though the financing of research at the universities is also largely by the government, a significant portion of it comes from contract or project bidding; as a result, research activities at the universities are not as stable, but they are more competitive and agile. They also respond directly to the needs and priorities of the consumers and contractors. At any rate, it is obvious that agricultural research in developing countries will continue to depend on public sector funding.

Perhaps the greatest financing problems in research, besides the relatively low total volume, are the marked yearly fluctuations (Trigo and Piñeiro, 1984) and rigid distribution in budgets. Diminishing operational funds frequently reduce work efficiency in research significantly. A rigorous analysis of this problem could point up new investment opportunities in research.

Table 4. Latin America: budget allocations for agricultural research in thousands of constant (1975) value currency for each country

Country	1960	1970	1980	Rate of annual variation 1980/1970 %
Argentina (000 pesos)	1,100	1,113	1,301	1.6
Bolivia (pesos)	10,820	30,980	36,680	1.7
Brazil (000 cruceiros)	67,316	196,569	949,561	17.1
Colombia (000 pesos)	213,800	667,900	697,100	0.4
Costa Rica (colones)	3,565	4,637	12,144	10.1
Chile (pesos)	13,702	41,174	33,208	–2.1
Ecuador (sucres)	–	72,628	99,666	3.2
El Salvador (colones)	1,178	1,280	3,906	11.8
Guatemala (quetzales)	1,840	1,911	3,485	6.2
Mexico (000 pesos)	58,300	30,900	579,500	34.1
Nicaragua (cordobas)	–	7,210	9,168	2.4
Panama (balboas)	417,000	1,176	1,622	3.3
Paraguay (000 guaranies)	–	68,200	441,100	20.5
Peru (000 soles)	76,900	351,800	161,200	–7.5
Uruguay (pesos)	215,000	372,000	818,000	8.2
Venezuela (bolivars)	19,851	–	97,700	8.2[a]

Source: Adapted from Trigo and Piñeiro, 1984; see exact sources in that publication

[a] Increase between 1960 and 1980

Note: Some figures do not correspond exactly to the cited year, but to a year close to it.

Research Programs and Priorities

Agricultural research activities are not subject to formal planning processes; that is, there are no effective mechanisms for coordinating and orienting research at national institutes, specialized institutions, and universities. Sometimes the national institution has great influence and acts as leader, as in the case of EMBRAPA, or it practically monopolizes research (except for specific crops which are studied separately) as in Ecuador's INIAP.

Because of the research systems' size, structure, and mode of financing, there are generally no great omissions or duplications that demand complex planning processes. In practice, the national institutes that dominate the scene take their guidelines from the national economic development programs and from institutional legislation to establish research themes. As can be observed in a review of the activities of all the institutes in the region, these themes tend to be very stable in spite of political change and marked budget fluctuations.

In other words, important decisions about research have a strong historic element that reflects the structure of agricultural production and its problems; adjustments in annual programs are made according to varying criteria and circumstances, but without major modifications. Extensive changes in planning and research themes take place only when there are significant institutional changes. This happened in Brazil when EMBRAPA was founded in 1974, in Peru with the transformation of SIPA, and in Colombia when ICA was assigned additional responsibilities in 1978. Foreign aid, either in the form of assistance programs or credit from international organizations, also effects changes, as in the case of IDIAP in Panama, ICTA in Guatemala, etc.

Starting from the major political lines that establish national development programs, each country has its own mechanisms for arriving at agricultural research programs and priorities; thus a generalized model for decision-making is not possible. Sometimes, as in Colombia, the national institute and the planning office are part of a national agricultural research plan (Chaparro *et al.*, 1981). In Brazil, EMBRAPA makes decisions internally, as part of a circular programming process in which the executives take their cue from the policies of the Ministry of Agriculture, the National Development Plan, and the National Science and Technology Development Plan, as well as from past research results (Sánchez and Barros, 1981). In Chile, INIA plans the programs internally, its Council approves them, and they are subject to the Ministry of Agriculture through budget allocation (Ortega, 1983). In Ecuador, INIAP makes up the programs, which are subject to revision and approval by the Ministries of Agriculture and Finance, and finally, by the National Congress; these government institutions, however, do not review research aspects, just budgetary ones (Iowa State University, 1982).

In spite of the different methods and criteria for establishing programs and priorities in national institutes and of the changes that have been introduced, it seems correct to conclude that, in general, researchers and administrators at the institutes have the greatest say in decision-making (within the general policies mentioned above). Programs are usually drafted from projects made up by researchers and approved by the institutes' executives and board of directors. This characteristic of the planning process may explain the long-term stability of research activities.

Beyond the definition of planning processes and priorities, examining the real distribution of research funds among products, problem areas, and/or disciplines is also useful. Unfortunately, reliable data are not available from all countries in the region; for this reason, I have resorted to using partial information to draw conclusions about budget allocations in agricultural research.

Table 5 presents the volume and distribution of funds at EMBRAPA for 1979 and the distribution for 1976 only. These figures indicate:

- The large number of research themes and the relatively low funds allocated to each—taking into account that EMBRAPA does not include coffee, cocoa beans, etc.,
- The relative stability in the allocation of funds[2] in spite of the fact that the total investment in constant value currency nearly doubled between 1976 and 1979.
- The very high priority assigned to cattle raising, even though it diminished in 1979.

Table 5. Brazil: EMBRAPA research expenditures, by projects

	Expenditures by projects, 1979		
Commodity	Millions of cruceiros	%	% of 1976 expenditures
Basic seeds	101.5	8.4	0.5
Beef	93.0	7.7	11.0
Soils	81.8	6.8	4.2
Dairy products	80.7	6.7	11.5
Fruits	76.4	6.4	8.8
Humid tropics	63.9	5.3	5.2
"Cerrados"	61.7	5.1	8.8
Vegetables	57.4	4.8	4.0
Maize	55.7	4.6	5.7
Semiarid tropics	53.7	4.5	4.2
Cotton	53.5	4.4	3.5
Beans	53.0	4.3	5.7
Rice	49.1	4.1	5.5
Cassava	46.6	3.9	2.8
Rubber	24.6	2.0	4.6
Sorghum	22.4	1.9	2.6
Soybean	19.9	1.6	1.5
Others	208.1	17.5	9.9
Total	1,203.0	100.0	100.0

Source: Adapted from Sanchez de Fonseca and R. Barros, 1981, Table 3

2 Especially if the definitions of some categories changed from one year to the next.

- The greater number of themes studied in 1979, judging by the classification "Others".

The distribution of total agricultural research spending in Colombia in 1973 and 1976 (80% of which went to ICA) is presented in Table 6. Once again, the enormous range of research programs, the low concentration of funds (without counting the first three general categories), the high priority given to cattle raising, and the relatively high ranking of basic food crops stand out. The stable financial distribution for both years is also worth noting.

It is interesting that Colombia has attempted to create sophisticated procedures to define research priorities (Chaparro *et al.*, 1981), which include various indicators of the socioeconomic importance of each product. A priority index to be used as a guide for

Table 6. Colombia: agricultural research spending at ICA and other institutions, in Colombian pesos, 1973 and 1976

	1973	1976		Ranking in estimated index[a] of general priorities
	%	Mill. Col. $	%	
Research centers	32.7	121.3	36.5	–
Basic research	14.1	48.1	14.5	–
Support research	7.1	28.4	8.5	–
Cattle (beef and dairy)	4.7	15.7	4.7	2.3
Coffee	4.9	15.5	4.7	1
Fish	5.7	15.3	4.6	–
Hogs	1.6	9.3	2.8	7
Oil seeds	2.5	7.8	2.3	20.22
Fruits and vegetables	2.4	7.7	2.3	8.16[b]
Maize and sorghum	2.7	7.5	2.2	13.17
Cassava and sweet potato	2.0	6.7	2.0	6.14
Rice	1.4	5.4	1.6	5
Poultry	1.6	5.1	1.5	10.12
Beans	1.8	4.9	1.5	18
Sugar cane (brown sugar)	0.6	4.7	1.4	9.11
Cocoa bean	1.7	4.7	1.4	21
Forestry products	–	4.2	1.3	–
Wheat	0.9	4.0	1.2	15
Cotton	1.1	3.0	0.9	4
Others	4.5	13.0	4.1	–
Total	100.0	332.3	100.0	

Source: Adapted from Chaparro, F. *et al*, 1981, tables 2 and 15.

[a] This index is based on 28 agricultural commodities which make up the largest part of Colombian production; index values fluctuate between 22.12 and 0.07

[b] Only bananas

programming research was made up from these indicators. Table 6 shows the position of each product according to its value on the index. Many of these coincide, at least in ranking order, with priorities established in 1976, except for some categories which are totally different, like cotton and oilseeds. This suggests that traditional "pragmatic" distribution in some way reflects estimated "theoretical" priorities.

The distribution of activities in Chile's agricultural research has been done according to the number of experiment units and projects that INIA and the universities have carried out over a period of years. Results appear in Table 7. In general, the same patterns are repeated, even the importance of cattle raising (pastureland plus livestock research would rank fi... on the list). Here, however, I wish to compare INIA's allocations to those of the universities. What stands out is the high proportion of basic research done by the latter, a fact that confirms interinstitutional distribution of basic and applied research. Also, more funds are concentrated on fewer categories, especially export products (fruits and vegetables); no doubt this is the result of financing through contracts by the Development Corporation, business enterprises, and others.

Table 7. Chile: research distribution by areas, 1976/1982 (total experimental units and projects[a])

Commodity	Total units		INIA		University	
	No.	%	No.	%	No.	%
Wheat	870	12.5	789	14.8	81	5.0
Fruits	768	11.0	439	8.2	329	20.4
Basic/support research	717	10.3	342	6.4	375	23.2
Prairies	702	10.1	601	11.2	101	6.2
Vineyards	488	7.0	401	7.5	87	5.4
Vegetables	480	6.9	352	6.6	128	8.0
Potato	452	6.5	415	7.8	37	2.3
Bean	341	4.9	318	5.9	23	1.4
Dairy products	337	4.8	208	3.9	129	8.0
Maize	280	4.0	218	4.1	62	3.9
Beef	232	3.3	163	3.1	69	4.2
Sheep	181	2.6	129	2.4	52	3.2
Lentils	164	2.4	161	3.0	3	0.2
Rapeseed	152	2.2	143	2.7	9	0.5
Rice	138	2.0	138	2.6	–	–
Oats, barley	122	1.8	116	2.2	6	0.4
Chickpea	110	1.6	104	1.9	6	0.4
Others	425	6.1	307	5.7	118	7.3
Total	6,959	100.0	5,344	100.0	1,615	100.0

Source: Adapted from Ortega, H., 1983

[a] The term "experimental unit" was used to assess INIA's work, and "project" was used for the universities; since these two concepts are different, a direct comparison between INIA and the universities cannot be made, but the distributions can be compared

Finally, Table 8 shows the situation in Peru, where a priority index similar to the Colombian version was set up though it differs in methodology (Paz, 1981). The resulting distribution seems to reflect the national situation accurately. There is another example of priority quantification in Venezuela (Gómez, 1977; Toro *et al.*, 1976) following similar methodology as in Colombia and Peru.

To sum it up, the cases cited above and observation of other countries in Latin America point tentatively to the following conclusions:

- There are no uniform, clearly defined procedures for establishing research priorities;

Table 8. Peru: estimated research priority index

Commodity	Index
Maize	3.30
Cotton	2.97
Potato	2.87
Sugar cane	2.83
Coffee	2.79
Peas	2.76
Wheat	2.71
Rice	2.63
Barley	2.61
Vineyards	2.49
Turnip	2.49
Plantains	2.36
Rubber	2.32
Beans	2.27
Pomaceous fruits	2.23
Tobacco	2.22
Cocoa bean	2.15
Citrus fruits	2.14
Sweet potato	2.09
Tea	2.06

Source: Paz, L., 1981

Note: This index includes 52 commodities, which all together total 100%.

- Although sophisticated methods have been tried for generating quantitative indices for research priorities, they have not gotten past the experimental stage;

- Actual funding and activities (programs) seem to be what one would expect in keeping with socioeconomic and agricultural criteria, though some products present significant discrepancies;

- There may be an excessive waste of efforts in terms of products and areas under study, in relation to total funding destined to research;

- There are no marked variations in the allocation of funds between one year and the next, at least in the brief periods that were studied.

Since annual research spending fluctuates widely (Trigo and Piñeiro, 1984), the last point is particularly interesting, for it indicates that the programs are not restructured (in response to changes in the budget) according to a priority criterion; on the contrary, budget variations are absorbed equally among all the categories that make up the programs. This hypothesis regarding the strategy for using financial resources is important for efficient research and suggests that all categories have a minimum priority, which means that they cannot be excluded when there is a shortage of funds. If this were the case, the first priority for new research investments would be a selective distribution among existing categories, but with marked differentiation according to relative priorities.

Productivity and Assessment of the National Agricultural Research Systems

As was mentioned before, practically speaking there are no effective institutional mechanisms for planning

agricultural research at the national level. Though at times this responsibility has been assigned to the National Science and Technology Councils (e.g., in Ecuador), or Councils for Agricultural Research have been created (as in Chile), these institutions do not have the capacity to orient or supervise the NARS, as the Consultative Group on International Agricultural Research (CGIAR) does over the international agricultural research centers.

Consequently, the assessment of NARS performance is imperfect and incomplete. For the same reason, there is little available information about productivity of research institutions and, in general, systematic and rigorous assessment methods are not used, or if they are, the results are not known; no doubt this situation contributes to the lack of public support for the NARS and the criticism directed at them.

The lack of general assessment does not mean that the national institutes themselves do not carry out internal analyses of their own research performance, but this is not enough to measure and justify productivity of agricultural research investments. As has been seen, there are very few benefit/cost studies in this field outside the ones EMBRAPA has done in Brazil (Cruz *et al.*, 1982 and Palma, 1983) and none of these was carried out at the request of the institutions themselves or of the CONACYT. Even simple assessment studies (for example, rigorously listing and quantifying the generated activities and products) are few.

An attempt was made to measure productivity (or "scientific creativity") of agricultural research in the different world regions relative to the value of agricultural product by estimating the number of publications in international journals from 1962 to 1968 (Evenson and Kislev, 1976). Latin America was last among all regions considered, as shown by the following figures:

Total annual publications per each US$100 million in agricultural products

Regions	No.
North America	8.9
Northern Europe	11.3
Southern Europe	5.9
Eastern Asia	4.3
Near East and North Africa	2.0
Latin America	1.8

This type of comparative analysis is much used in scientific and technological circles in all fields, as exemplified by work done at the Institute for Scientific Information in the USA (Garfield, 1983). This kind of study would be very useful, particularly for agricultural sciences. Some studies in Brazil (Sánchez de Fonseca, 1981) bring out the increase in agricultural literature since 1920 and compare the number of publications per crop, researcher, and other criteria. A survey done in Chile (results appear in Table 9) (Cañas, 1981) is interesting because it compares productivity at various institutions.

Perspectives on Traditional Agricultural Research

Agricultural Development, Technological Change, and Research Investment

Satisfying the demand for food and raw materials and agricultural development in Latin America in the future will depend on the massive adoption of new technologies that raise rural productivity. Most of these technologies will be specific to unique local characteristics such as soil, climate, and biological conditions; they will therefore have to be generated nationally or adapted by the national research systems, not imported.

In the preceding sections, I attempted to show that the NARS have progressed significantly in the last decades, even though many institutional and organizational weaknesses still persist and will require considerable investment to correct in decades to come. I also tried to demonstrate that there is not enough investment in agricultural research in the region and that perhaps the current budgetary allocation among crops, areas, and disciplines is not socially the best.

From all these facts, I conclude that there is need and opportunity for increasing research investment in the next few years. The International Food Policy Research Institute (IFPRI) projected the need for financial resources for agricultural research in developing countries to 1990 (Oram *et al.*, 1979); figures for Latin America are presented in Table 3. Annual rates of increase in projected research expenditures are generally high and above the growth rates of the farm GNP of the last decade. They are extraordinarily high in smaller countries or countries whose NARS are less developed. Nevertheless, Latin American experience in 1970/1980 indicates that it is possible to increase research expenditures at a very high rate (Table 4), as was the case in Brazil, El Salvador, Mexico, and Paraguay.

Even without considering possible new research technologies that result from molecular biology, biochemistry, and other basic sciences, the question is where to place the new investments in traditional agricultural research. This question once again brings up the subject of planning and defining research priorities: how should this task be carried out in the future? Can the problems or productive themes to be studied by traditional research be foreseen?

Improving Decision-Making in Research

During the last decades, industrialized nations made much progress in setting up more formal methods for research decision-making. Three main approaches were: point distribution methods, cost/benefit methods, and

Table 9. Chile: scientific productivity in agriculture, by institutions, 1979/1980

Institution	Articles No.	Journals and conferences %	Researchers No.	Researchers %	Pub/person
INIA	100	24.9	161	25.5	0.68
U. of Chile	139	31.5	229	36.3	0.61
Catholic U.	76	17.2	34	5.4	2.22
Concepcion U.	24	5.4	35	5.5	0.67
Austral U.	70	15.9	94	14.9	0.50
Others	22	5.0	77	12.2	0.29
Total	441	100.0	630	100.0	0.70

Source: Cañas, R., 1981

Note: The publications and papers included in the study cover 90% of all such activities in Chile. The number of researchers includes all the full-time professionals that are involved in research, without specifying the time they actually dedicate to it.

experimental approaches (Ruttan, 1982). Nevertheless, Ruttan, one of the most notable experts on the subject, holds that the contribution of these methods to research decision-making is conditioned to effective interaction among researchers, planners, administrators, users, and participants in the legislative process. In other words, the creation of a political environment that ensures public support for research is emphasized (Ruttan, ibid).

All this suggests that much more progress has to be made in institutional methods and mechanisms for defining programs and research priorities. This need becomes more urgent as the NARS expand and diversify and as the universities collaborate and compete with the national research institutes.

The establishing of research policies, programs, and priorities should be carried out at three levels in which the main elements are different but interact continuously to achieve a more efficient fund distribution that is consistent with national objectives.

At the first level, which is made up of public officials, economists, and politicians who participate in national development programs and planning, the basic policies and objectives for the agricultural sector are defined; from these derive the general guidelines for the science and technology research system. Among the objectives and policies that affect research decisions, the following are significant:

- the expected growth rate of the farm GNP;
- the generation (or saving) of foreign currency in the sector;
- the social emphasis on small farmers;
- the degree of national food self-sufficiency;
- employment rates in the agricultural sector;
- the incorporation of unpopulated or jungle regions.

It is evident that research is only one of many socioeconomic policy instruments that governments handle, and not the most efficient one to solve some of the problems mentioned above. Nonetheless, today the notion that science and technology in developing countries should be directed at solving the most important or urgent national problems is more and more prevalent. In the agricultural sector, this means that the NARS have to recognize and assimilate general guidelines and obligations.

At the second level, general guidelines should be translated into qualitative and quantitative definitions of problems or research themes. That is, the definition of which crops or livestock products have social priority, which regions, which groups of producers, or which problems (soil, irrigation, etc.).

Projections for production and consumption of agricultural products, presented at this workshop by Valdés, are the first valuable indicator for directing agrarian policy and research, but more information is required for establishing research programs. The methodologies mentioned above are particularly useful here. for their development and application demand close cooperation between agricultural researchers and economists. Here are some elements to be taken into account:

- the relative product participation in the total value of agricultural products;
- product participation in domestic and export markets;
- the contribution by the product toward generating employment;
- real and potential cultivated land;
- product participation in the family consumer basket;

- product importance as industrial raw material.

This brief enumeration does not do justice to the methodological complexity and information that these techniques for assessing priorities demand, but it is useful because it calls researchers' attention to the type of problem that confronts decision-makers and those who allocate public funds. Unless the NARS try to solve these problems in the future, they will not rally enough public support for their work.

Finally, at the internal operational level of the NARS, (and the national institutes, in particular), general priorities for crops or products should be translated into specific programs and projects for products, areas, methods, etc., as well as concrete priorities for research. Two types of data are necessary for this phase:

a) National agricultural data (cost structure, management practices and problems, possible savings, possible degree of technology adoption) and

b) Scientific knowledge data that are useful for solving different problems (adequate research methods, estimated research and development costs, project duration, probability of reaching scientific and technical objectives).

At this decision level, the permanent participation and cooperation of researchers and other parties who are interested in agricultural science and technology become more necessary. Producers, processors, agribusinessmen, agricultural economists, and extension agents have greater knowledge of the first aspect (a) while researchers, specialized scientists, and research administrators have more knowledge of the second one (b). The NARS and their individual components should be organized in such a way that they aid cooperation among these groups. Efficient mechanisms at this level can be the best guarantee of independence and freedom of action for researchers because they ensure an environment where scientists are effectively linked to research clientele. This will also promote public and financial support for the research system. Once again, the assessment of earlier research results is important, since it is the best way of accurately determining the points included in the second aspect (b).

Agricultural Research Tasks in the Next Few Years

Given the broad range of crops and livestock products, as well as agroclimatic, socioeconomic, marketing, and institutional conditions that characterize Latin American countries, it may seem risky to make judgments on the course conventional agricultural research will take in the next decades, especially given the lack of systematic studies and projections. In spite of these reservations, it is possible to get an idea of the subjects that will undoubtedly be preferred themes of the NARS in coming years, considering the situation and experience of agricultural research in the last decades, as well as partial information, studies, and regional and national projections.

Production of nearly all agricultural products and especially of basic foodstuffs (cereals, legumes, meat, etc.) should rise, though in many cases only through increasing yields per hectare. Which crops and livestock products present the greatest differences between actual and potential yields and what the potential is for eliminating these differences are both empirical questions.

In general terms, industrialized nations have significantly higher yields which have increased at high stable rates from 1965 to 1982. In contrast, Latin American countries are very heterogeneous in both aspects, especially in the frequent negative rates of change in yields (for example, cassava, beans, sugar cane, cotton). In addition to economic policy factors that affect these results, there are technological limitations that hinder the improvement of productivity. The significant differences in yields (under similar agroclimatic conditions) also suggest that many countries have not exploited their technological potential. These observations, which can be applied to all the important products of the region, confirm the conclusions named above on the general need to increase agricultural research (in other words, research at present is barely enough to fulfill the minimum required priorities for agricultural products of the region). This coincides with the idea that the first priority is "maintenance" research, that is, research that constantly generates crop varieties or farming practices that keep yields from diminishing because of new pests or pathogenic organisms.

From this basic idea, the most important or frequent problems in agriculture which demand solutions based on locally developed science and technology must be determined. Information on such problems is provided by technical agronomic studies and by the opinions of experts and scientists. An example of the results generated by this type of study is presented in Table 10, which includes data for seven crops in three Latin American subregions (Iowa State University, 1982).

In spite of some differences in emphasis and priority, there are four main themes, presented here in order of importance:

- The creation of new high-yielding varieties and/or varieties that are disease resistant and/or adapt better to local conditions.
- Disease control (via resistance and biological or chemical control).
- Improved farming practices (soil preparation, fertilization, weeding, etc.).
- Pest control (insects, nematodes, rodents, etc.).

It seems clear that in terms of the disciplines involved in crop research, the highest priority is given to genetics, phytopathology, entomology, soils, and farming practices. According to previous experience in organizing research, most of these disciplines should specialize in one crop, or interdisciplinary teams should be formed for solving all the problems that affect crop yields.

There is the technological challenge of limiting expenditures on modern inputs per unit as yields increase (Alves, 1983) because of the effect of input costs on food prices and on the large low-income groups in the region. This implies that research should pay more attention to biological disease and pest control, nitrogen fixation, cultural practices that save on inputs, etc. In this context, research potential being opened up by bioengineering (the topic of another conference in this workshop) is especially important. All these forms of research are significant because they generate technology for the small farmer.

Table 10. Latin America: main research problems in basic crops and pastures, by regions

Crop	Mexico and Central America	Andean Zone	Brazil and Southern Cone
Maize	Insects	High yield varieties	Cultural practices, fertilization
	Diseases	Insects	Disease resistance
	Plant architecture	Diseases	Toxic soil tolerance
	Weed control	Lodging	
	Localized adaptation		
Wheat	Diseases (blight, rust)	Diseases (rust, etc.)	Disease resistance
	Cultural practices	High-yield varieties	Disease control
		Cultural practices, weeds	Production technologies weeds
			Bread flour qualities
Rice	Diseases	Diseases	High-yield varieties
			Diseases
	Weed control	Weeds	Grain quality
	Salt tolerant varieties	High-yield varieties	
		Saline soils	Practices, fertilization, weeds
Beans	Diversity of varieties	Diseases	Diseases
	Multiple cropping practices	Insects	Fertilization
	Diseases	Variety production	Cultural management
	Fertilization management	Agronomic practices	Insects, weeds
	Mechanization		
Cassava	New varieties	High-yield varieties	Genetic material
		Diseases	
		Post harvest management	Diseases and pests
			Production systems
		Technology production	Mechanization
Potato	Seed varieties	Seed production	Seed production
	Diseases (late blight)	Diseases	Disease and virus resistance
		Viruses	
	Nematodes	Insects, nematodes	
Tropical pastures	Growth of leguminous pastures	Management and technology	Management, production system
		Acid soil varieties	Varieties for acid soils
	Soil management at high altitudes	Leguminous pastures	Leguminous varieties for acid soils
		Pests and diseases	Soils

Source: Iowa State University, 1982

The political, social, and economic importance of the small farmer will put growing pressure on the NARS to devote a larger portion of their resources to solving the problems of this sector. The task presents a special problem in regard to production systems, which was discussed in another paper of the workshop. Nevertheless, the research approach would not alter the basic aspects of priorities by products and disciplines, since the weight of the "small farmer" factor would already be included in priority definition.

Another problem will be the generation of basic knowledge and technology for vast regions of Latin America which depend on this information for their progressive incorporation into the production process. This is the case in the Amazon, the jungle, the prairies, the "cerrados", the tropical zones in Mexico, etc. In some of these areas ecological conservation will be very important (Fearnside, 1983).

The worldwide energy problem also poses some new situations for agricultural research in the region. On the one hand, it is necessary to save fuel (this implies addressing engineering aspects in agriculture which traditionally have been ignored), and on the other, efforts must be made to manufacture fuel from vegetable sources. The first situation refers to cultural practices and mechanization; the second points up the priority of forestry, energy crops such as sugar cane and oilseeds, and of techniques for exploiting farm by-products.

Cattle raising (meat and dairy products) will have an ever more important place because of the expected increase in consumption as the per capita income of the region goes up. This suggests that pastureland research—especially on difficult soils—will increase, as will research in management practices that can raise yields (e.g., dairy products in tropical zones).

Finally, many countries can be expected to increase their exports more than usual, as a long-term result of the high foreign debt in Latin America. This will underline the importance of products such as coffee, sugar cane, cotton, etc., but it will also emphasize the importance of basic products that substitute for imports. Agricultural research will play an important role in the new business and production strategies that the current international situation will bring about.

Before closing and without going into detail, I wish to point out the great opportunity and convenience of more extensive international cooperation in agricultural research (Venezian, 1984), which could be very profitable in all the fields mentioned above and merits special attention in determining future investments.

Conclusions

On analyzing investment opportunities in the traditional forms of agricultural research in the next 10 or 15 years, the following conclusions can be reached:

a) There have been great advances in nearly all the countries of the region in the development of national agricultural research systems centered around a national institute; today there is a solid institutional base, which, though not problem-free, is capable of absorbing new investments with the perspective of reasonably high social productivity.

b) It is estimated that agricultural research investment in the region has been less than is socially convenient, judging by the different

assessment criteria. There is, however, a lack of procedures for the systematic assessment of research results and studies on research productivity.

c) Criteria and procedures for programming and defining priorities in research are heterogeneous and usually poorly developed in Latin American countries. Most of the responsibility for decisions on distribution of funds among products and/or disciplines belongs to administrators and researchers at the national institutes. Various mechanisms for decision-making in research have been tried, but there are no conclusive results. In some cases there are discrepancies between "theoretical" priorities and the ones revealed by actual spending and research activities.

d) In general, research covers a broad range of products, areas, and problems, judging by the distribution of research funds. This situation is maintained perhaps due to low financial resources, public demands that do not allow certain products to be overlooked, and the internal decision-making procedures at research institutes.

e) Agricultural development projections, the growing demand for food and raw materials, and the potential yield increases suggested by comparative international data lead me to conclude that agricultural research investment should increase significantly in the next few years. The projected rate of increase varies widely from country to country and is generally higher for smaller nations. Past experience shows that it is possible to reach these rates.

f) Products and disciplines that could receive greater attention in agricultural research are so numerous that it is not possible to advance specific conclusions. In general, however, "maintenance" research on important crops will have first priority; research aimed at increasing yields of basic food crops and livestock products will continue to be first priority; genetics, variety improvement, phytopathology, soil and farmer practices, and entomology will demand the most work; biological control, resistant varieties, and other techniques that save on modern inputs will merit higher priority; technology development for the small farmer will become more important; more basic and technological research will be required to make fallow lands productive; crops and techniques which contribute to solving the energy problem will merit more attention; and research on exportable products and products that substitute for imports will play a more significant role in solving the foreign debt problem.

g) Finally, the opportunity presented by regional cooperation (among countries and research centers) in many research themes to be studied in the future should be pointed out. Latin American experience on this matter has been positive and a high return on investments in this type of program is to be expected.

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Comment

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I have learned a great deal from Venezian's paper. It convinces me that I know all too little about agricultural research realities throughout Latin America. The very first paragraph is a gem. It is concise and to the point on the fundamental importance of the production and distribution of advances in agricultural knowledge.

My comment is not a critique, for reasons already implied. It is intended as a supplement in which I shall feature some additional properties of agricultural research.

1. Agricultural research produces substitutes for agricultural land. In effect it augments the supply of such land. The Ricardian concept of the supply of land has lost its sting.[1] The Club of Rome would be well-advised to investigate these effects of agricultural research which augment land supply.

2. Agricultual research contributes substantially to the secular reductions in real costs of producing food. Poor families benefit much more than rich families from declines in the cost of food; thus, over the long pull, agricultural research has had and continues to have a significant effect on reducing the income inequalities within populations.

3. The remarkable increases in life span in most low-income countries during the last three decades (average life span in India, for example, increased 62% from 1951 to 1981) could not have occurred had the supply of food declined. High-yielding food grain varieties, the battle flag of agricultural researchers, contributed to per capita food increases despite rapid population growth. People place a high value on the longer life span here under consideration.

4. In no small part as a consequence of the success of the Mexican high-yielding wheat in the Punjab, the school attendance of farm children doubled. In my economic accounting, part of the credit for this increase belongs to agricultural research which was done here in Mexico.

5. Indra Makhija, in her research on the economic behavior of rural households in India, discovered that families on farms using the new high-yielding crop varieties had a significantly larger decline in fertility than families on farms not benefitting from any of the new high-yielding varieties. Richard Critchfield has argued that families, seeing the benefits from scientific advances in farming, will also seek to benefit from them by using modern means of birth control.

6. Agricultural research is plant specific, animal specific and, in large measure, location specific. It is not a pin factory that produces a highly standardized, homogeneous product. The issues that do not get on our research organization and financing

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1 See Dr. Schultz' "The Declining Economic Importance of Agricultural Land," which was published in Economic Journal, 61, December 1951, pp. 725-740.

agenda are: (1) What are the scientific agricultural research possibilities? On this issue, we should be specific for each class or type of research. (2) Which research hypotheses are compelling and promising? (3) At which point does agricultural research become overorganized in the sense that it impairs the creativity of agricultural researchers?

Job of Economists

One of the fundamentals of economics is the concept of comparative advantage. Agricultural research priorities that are not based on the comparative advantage of the particular agricultural activity being served by research are counter-productive priorities. It is the job of economists to provide information on this issue.

An assessment of the prevailing and prospective comparative advantage of each crop and animal product, by country and within each country, is called for, given the endowments, the prospective additions to the stocks of physical and human capital, and the state of domestic and international trade.

I dealt with this issue as it applies to the Caribbean entities in "The Economic Value of Human Capital and Research: Puerto Rico and the Caribbean", at the University of Puerto Rico, May 10-11, 1984.[2]

Competent economic studies show that most major countries of South America have for decades been selling their intrinsic comparative advantage in agriculture short. The key to this long-standing impairment of the economic possibilities of agriculture is revealed in the distortions of agricultural incentives. No country whose government distorts agricultural incentives can benefit fully from the contributions of agricultural research. Consider, for example, the increases in agricultural production derived from high-yielding wheat varieties. The best production successes have occurred in market economies in which incentives have been least distorted. Optimal economic incentives would be reliable signals for determining research priorities. In the case of agriculture, these incentives are at their worst in the Soviet type of economy. While less bad, they are far from optimal in Latin America.

Here are two examples which help to clarify the issue when agriculture research is inconsistent with the fundamentals of comparative advantage. (1) The research emphasis that is being placed on food production throughout much of Central (tropical) Africa is a serious mistake in view of the fact that the economic comparative advantage was, and continues to be, in the larger gains in real income to be had from agricultural research, which increase the productivity of agricultural exports, primarily of tree and fiber crops. (2) I venture, at some risk, to express my economic judgment on Brazil's research expenditures on substituting fuel made from cane sugar for gasoline made from imported petroleum. The cost of producing cane sugar is far too high to compete with oil at, say, $28 per barrel. This costly research enterprise is based on a mistaken conception of the economic comparative advantage of sugar relative to oil despite what OPEC has done to oil prices.

My bottom line is: the economic value of agricultural research is larger than we think, and it would be larger still were it not for the distortions in agricultural incentives.

2 Human Capital Paper No. 84-2, Development of Economics, University of Chicago.

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Research in On-Farm Production: Main Ideas, Problems, and Implementation Opportunities

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Introduction

The object of this paper is to review the problems and opportunities inherent to the development of on-farm research as a necessary complement of the more traditional types of agricultural research. This innovation in the conventional methodology of agricultural research has been promoted by various national and international organizations that generate and transfer agricultural technology. It is presently becoming institutionalized in a number of Latin American and Caribbean countries.

The on-farm program has taken its place within agricultural research, not with the purpose of expanding the frontiers of science but of using existing scientific and technological knowledge to solve priority problems of representative farmers. In other words, the aim is to increase the efficiency of national programs in the development and extension of technologies appropriate to farmers.

In spite of the considerable technological progress gained through research, there is a wide gap between the productivity potentials of modern technology and the production realities in many regions of Latin America. In a number of cases, after long and costly research efforts, the recommendations of research and extension systems have not been adopted by target farmers. Various reasons have been brought forward for this difference between recommendations and actual farmer practices. Among them have been the farmer's traditionalism and resistance to change, the inefficiency of extension systems in bringing him new technology, as well as reasons having to do with such factors as agricultural policy on available inputs, marketing, and pricing. All of these reasons are valid in certain cases. Nevertheless, it has been shown that, although farmers may have scant resources and little access to inputs, information, and markets, they accept some technologies and reject others. This would suggest that greater attention be paid to the suitability of technology recommendations in relation to farmer circumstances and, at the same time, more attention be given to the technology development and extension system.

For these reasons, production research on farmers' fields is considered complementary to traditional agricultural research. Its development can help to close the technological gap and increase the efficiency of the national agricultural technology development and extension system. These ideas are developed in greater detail in the various sections of this paper. In the following section a conceptual framework is set forth for a better understanding of the elements that affect the efficiency of agricultural

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research and the role of research in agricultural production. The third section is a review of on-farm research procedures, placing it within technology development and extension activities. The fourth section covers material related to production research and its eventual institutionalization in countries where it has been used. The fifth analyzes possible modifications in institutional structure and incentives that can strengthen production research. Finally, in the sixth section, conclusions and recommendations for organizations offering technical and financial assistance are presented. These conclusions point out the opportunities presented by production research for increasing the efficiency of the development and extension of improved agricultural technology in Latin America.

The Conceptual Framework

The effectiveness of agricultural research, as measured by the degree of technological progress observed and the resulting productivity levels, is partly the result of the economic policy of a country, for it creates an economic environment that promotes the profitability and, therefore, the adoption of improved technology. It is also the result of the orientation of technology development and extension institutions that produce optional technologies that farmers could adopt.

It was once thought that the economic conduct of farmers who choose between alternative technologies limited research effectiveness, but this has been proved wrong. The results of numerous studies carried out to explain the adoption—or rejection—of technological recommendations have led to the following conclusions: (1) that farmers, even poor ones who produce mainly for their own consumption, act deliberately in the adoption or non-adoption of technology; that they seek ways to increase their income while holding risks at acceptable levels; that they are conscious of changes in their economic environment and that they are reasonably efficient in using the scant resources available to them; (2) that although many interrelated factors influence the farmer's choice of alternative technologies, the physical (climate and soil), biological (pests and weeds) and socioeconomic (allotment of resources, access to markets, prices, and food preferences) circumstances are the ones that predominate.

In those countries which have shown great effectiveness in agricultural research and, therefore, in generating agricultural technology, economic policy is coordinated with technology development and extension organizations. The technological process can be divided into four interdependent levels, such as those described by Trigo *et al.* (1982).

Level 1: Linkage between society and technology generation—This level results when the system for technology development and extension—its objectives, organization, and execution—is consistent with the interests of the dominant governing groups.

Level 2: Linkage between economic policy and real demand for technology—This level is reached when the economic policy of the country (prices and taxes on inputs and products) is consistent with the objective of technological progress based on a more intensive use of various production factors.

Level 3: Linkage between technology generation and demand—This level comes about when target groups have adequate means of expressing their needs for technology and/or when the

technology development and extension system has adequate procedures for identifying priority problems and solving them.

Level 4: Linkage among the different components of the technology development and extension system—This level has been reached when the various components of the technology development and extension system (public sector organizations, international centers and agribusinesses in the production and marketing of goods and services) function in a coordinated manner.

Linkage within these four levels quarantees an integrated technological process which results in the relatively rapid development and adoption of improved technologies that are consistent with comparative advantages, allotment of resources, and the goals of farmers and related institutions.

As a result of peculiarities in the development of Latin American countries, especially as concerns their relationships with industrialized nations, there is a set of characteristics that hinders linkage in the technological process. Nevertheless, after costly experimentation, the inconsistencies within Levels 1 and 2 are disappearing, creating the conditions necessary for further technological progress. Under these conditions, Levels 3 and 4, which depend to a great extent on the existence and functioning of the organizations for technology development and extension, can help explain the inadequacy of the existing body of improved technologies. Within these levels, technological needs of the client (farmer demand) are translated into the development of adequate technologies (by the responsible institutions), leading to consistency between the research process and its results (technology recommendations) and the transferring of technology and its later adoption and use by the farmers.

This paper maintains the hypothesis that, in most Latin American countries, the public sector does not carry out research and that there are no organizations within the private sector which convert the findings of the technology development and extension system into appropriate technologies for representative farmers. This absence is responsible for the existence of an ample supply of technology (the inventory of improved technologies at experiment stations) which in many cases is irrelevant to the needs of large groups of farmers.[1]

In view of adoption studies, pioneer work by Schultz (1966), and the daily experience of people responsible for the development and extension of agricultural technology, it can be stated that, although there are many variables that influence the farmer's choice of alternative technologies, income and risk avoidance are the most important. Both are greatly affected by natural and socioeconomic circumstances of the target farmer. The effectiveness of agricultural research, as measured by the ample acceptance of the recommendations of the development and extension system, will depend on the ability to generate alternative technologies that are consistent with farmers' natural and socioeconomic circumstances.

It has already been suggested that the lack of methods and organizations for converting research results into technologies that are appropriate for representative farmers is the main

1 See Perrin and Winkelmann, 1976.

difficulty in achieving more consistency in linkage Levels 3 and 4. Here these methods are summed up as production research on farmers' fields and discussed further in the section "Methodology Review". It is important that they explicitly include the farmer and his circumstances (both natural and socioeconomic) in the orientation of technology development and extension activities.

The private organizations we mentioned are part of the technology development and extension system. They are the go-between between the system and the farmers and they attempt to adapt existing knowledge to specific production problems. These organizations, which are just beginning to appear in most Latin American countries, can consist of groups of farmers, such as the National Federation of Coffee Growers of Colombia (FEDERACAFE) and the Argentine Association of Regional Societies for Agricultural Experimentation (ACREA), formed specifically to serve groups of farmers and solve problems that result from linkage Level 3. Also included in this group are the agribusinesses in the production and marketing of inputs and services for agriculture. It must be pointed out that, in those countries which have highly successful agricultural research, there is a tendency to emphasize public sector contributions without due recognition of the role private organizations play in translating research findings into technologies for solving farmers' priority problems.

In the section on "Research Structure and Incentives", we indicate that in spite of the growth of private organizations, public sector organizations could greatly strengthen their work by using methods based on identifying priority production problems of representative farmers and applying research and extension resources to solve them.

Methodology Review

Before giving a brief description of the methodology for production research on farmers' fields, there are five concepts that should be discussed.

First, production research is oriented towards producing alternative technologies in the short or medium term. It attempts to identify the most promising research opportunities in order to concentrate limited research resources in those areas.

Second, according to short or medium term orientation, research problems and opportunities are determined within a systems perspective[2] that places target activities (crops and/or agronomic practices) in the production system prevalent in the area.

Third, since research is aimed directly at the farmer, who is equally concerned with physical and economic factors that affect production decisions, the methodology demands team work of biological and social scientists at all stages of the research process.

Fourth, production research methodology is directed toward bringing suitable, but not necessarily optimum, technologies to a target group of farmers; this goal is clearly not within the capacity of the development and extension system. Experience has shown that, on adopting a technological component, the farmer adjusts the recommended practice according to his particular set of circumstances.

2 Relevant interactions within the system or between its components and the farmer's resources are taken into account.

Finally, the adoption of technologies by the farmers is a sequential process of learning by doing. The methodology is geared toward the development of simple alternative technologies, to be adopted in stages leading out of farmers' circumstances and practices, instead of a complete technological package that incorporates a number of components. Such a package would present difficulties in the demand (farmer's capacity for debt and risk taking) as well as in the supply (lack of a multifaceted research process to determine components of the package).

Production research on farmers' fields includes a series of stages:

Farmer circumstances—Farmer circumstances are defined here as the factors on which the farmer bases his selection of technologies for use within his production system. Figure 1 presents the physical and socioeconomic circumstances that determine the production system and affect the selection of technologies. Agricultural policy and the distribution of resources by the farmer among the various activities within his farming system help determine the activity that will be studied within target crops or livestock. A series of informal (exploratory) and formal interviews are held with the farmers to identify existing production systems, prevalent agricultural practices, and the farmers' perceptions of priority problems and opportunities.

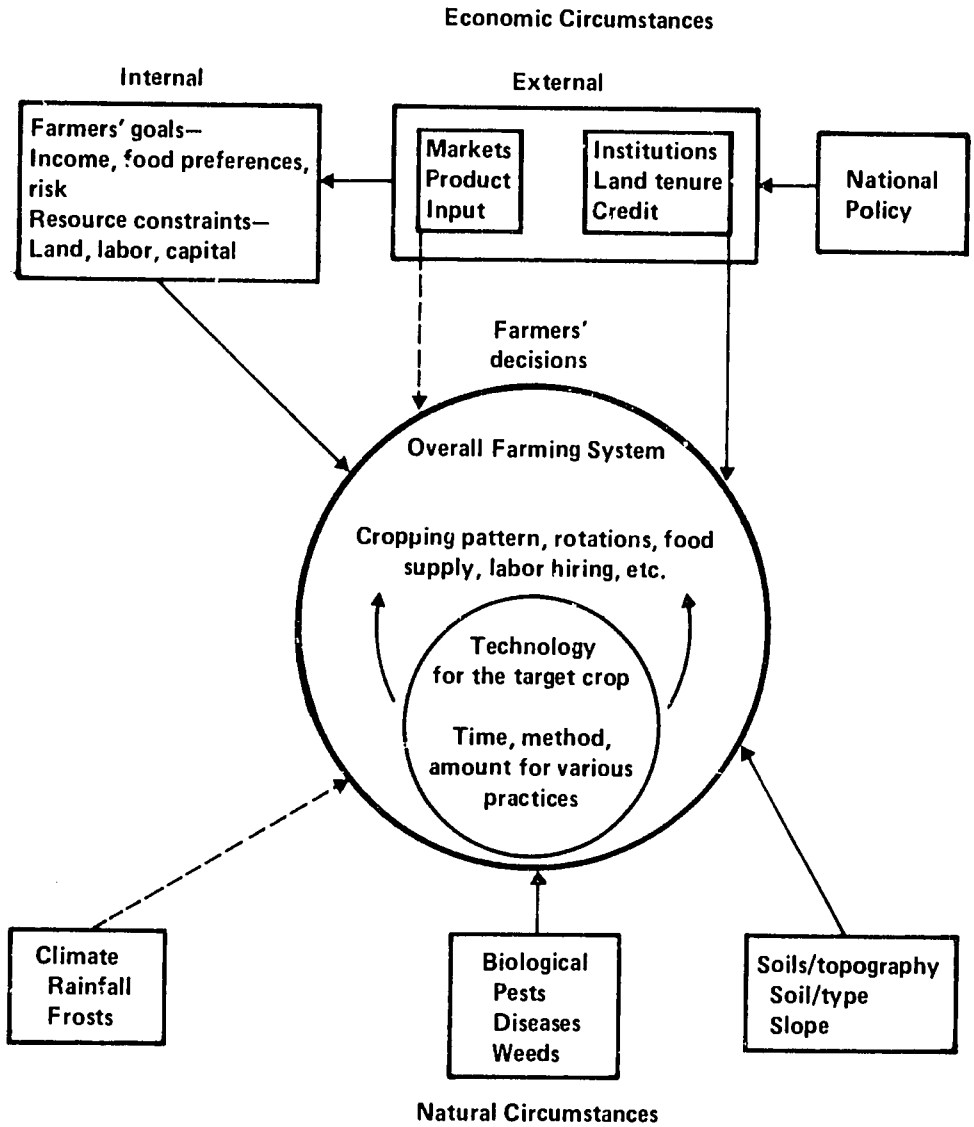
The sources of problems may be physical (pests, weeds, a variety with too long a cycle) or socioeconomic (allotment of resources, access to inputs). Problems that can apparently be solved through research become research opportunities.

Recommendation domains—Recommendation domains are groups of representative farmers to whom technology is directed. A domain's physical and socioeconomic circumstances are sufficiently similar for a given recommendation to be suitable for the entire group. These relatively homogeneous groups are determined according to the identification of production problems and research opportunities. Two farmers within the same domain share at least one problem or opportunity. The definition of recommendation domain is tentative and dynamic. It is a resource to be used to give direction to technology development and extension and not as an end in itself.

Selection of research opportunities and organization of the experiments—This is the stage where the information obtained through surveys and translated into problems and opportunities is integrated into the researchers' perceptions in order to arrive at a minimum set of experimental variables to be incorporated into the on-farm trials. Some of the identified problems will require experiment station study.

Trial conduction and recommendations—The various types of experiments (exploratory levels, and verification) are conducted on fields of representative farmers within the recommendation domain. The nonexperimental variables are handled at the farmers' level. At the end of the cycle, an integrated agronomic, statistical, and economic analysis is made of the results; from this analysis, decisions can be made as to whether the research should continue and what the recommendations are for farmers and, eventually, for agricultural policy. If the essential elements of farmers' demand for technology have been adequately met, the resulting recommendations can be made known rapidly.

Figure 1. Some agroeconomic circumstances that affect farmers' decisions in relation to the selection of crop technologies



--- Circumstances that are the main source of doubt in decision-making

Source: Byerlee, D. *et al.* Planning technologies appropriate to farmers: concepts and procedures; CIMMYT, Mexico, 1983. p. 10

Figure 2 shows an integrated plan for on-farm research which presents its linkage to agricultural policy and its close relationship to the experiment stations.

Operation and Institutionalization

Incorporating the methods for on-farm production research into conventional programs of technology development and extension is not easy.

The material presented in the preceding section reviews the roles of production research, experiment station research, extension, and agricultural policy within the integrated program of technology development and transfer. It particularly points out the complementary and integrated nature of production research.

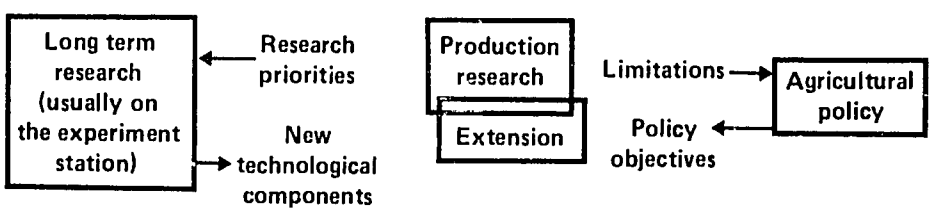
The conventional focus of technology development and extension presents certain problems. One is the gap between the experiment station researcher and the target of that research, defined here as the representative farmer. Many studies have been motivated by professional interests in solving agronomic problems that limit soil productivity, such as increasing potential yields of varieties, eliminating weeds and restoring soil fertility. At times, even when research has been directed at solving farmers' problems (not always representative), the focus has been top-down, that is, research on experiment stations is carried out under conditions that are very different from those of representative farmers; the results are then given to the extension service to be transferred.

An exception to this are fertility trials that have been carried out mainly on farmers' fields; however, the relevance of the results is questionable due to complementary cultural practices—soil preparation, weed control, etc.—being carried out according to optimum agronomic standards that are consistent with the creation of technology packages.

Also important is the gap between the extension worker and the target farmers. In this case, the size of the gap depends on how people responsible for technology extension have perceived the problems inherent to the process of technology adoption.

Two outstanding examples are: (a) an extension policy based on educating the farmer in decision-making. This presupposes that the farmer is not entirely capable of operating a business, and that the most important limitation in increasing productivity is the lack of business skills for operating a farm. This supposition creates a top-down situation, with work going into bettering the business skills of the farmer rather than identifying his problems and the research opportunities that can result from them. (b) An extension policy based on technical assistance. There is direct contact between the extension worker

Figure 2. Diagram for an integrated research program



and the farmer in order to make available technology (usually through informative pamphlets published by the experiment stations) that is relevant to each farmer's particular conditions. This assumes the existence of suitable technology, available from the experiment stations, and also that adoption can be achieved by increasing extension activities. Here again, there is no way to visualize the needs and limitations within which the farmer operates in his system of production. Therefore, no guide exists for gearing research to farmers' needs or for preselecting alternative technologies based on farmer circumstances.

Production research on farmers' fields can be seen as a link in the development/extension process, which reaches the farmer without elements of indoctrination (he needs to be educated) or discipline (he needs weed control). This type of coming together helps the worker to communicate with the farmer, examining with him the ways in which natural and socioeconomic circumstances affect his production decisions, and pointing out the limitations and opportunities that can eventually be included in agricultural research. In this way, on-farm production research offers an opportunity for closing the gaps between researchers and farmers and between extension workers and farmers.

Four important characteristics distinguish on-farm production research:

a. The emphasis is on solving specific production problems. Research is carried out in a limited geographical area, attempting to identify, within the framework of national agricultural policy, common problems and high priority opportunities for a target group of farmers. The results of this process are alternative technologies that can be adopted in the least possible time.

b. Problems and opportunities are identified within the short or medium term. In other words, the objective is to develop alternative technologies in the least possible time.

c. The identification of research problems and opportunities is carried out with explicit acknowledgement of the importance of the interactions within the farmer's production system (systems perspective).

d. Research opportunities are translated into hypotheses and experimental variables to be incorporated into trials on the fields of representative farmers within the recommendation domain.

For production research on farmers' fields to be effective, it must be part of a broader program, which is linked closely to long-term research usually carried out on experiment stations, as well as to the extension service. When there is a solid production research program, research done on experiment stations can be focused mainly on the development of new technological components whose creation calls for a higher degree of control over experimental conditions than is possible on farmers' fields. Starting with identification of problems and opportunities, production research should help determine priorities for trials to be carried out on experiment stations.

Production research depends on the technological supply of the experiment stations in order to design alternative technologies that respond to specific problems and opportunities. Workers who have the prime responsibility for extension, promotion, and diffusion should take part in the production research process from the beginning. As the process moves forward and the alternative technologies developed begin to be tested in verification trials and on demonstration plots, the participation of extension workers is greater. They can even be made

directly responsible for the conduction of verification trials and demonstrations.

The fundamental idea here is that work that goes from the experiment station toward farmers' fields through extension should not be carried out like a relay race where each participant hands the finished product to the next in line. In the integrated technology development and diffusion process, there is continuous interaction among the experiment station researcher, the production researcher, and the extension worker, according to the comparative advantage each brings to farmer circumstances.

Agricultural policy for reaching government development objectives has an influence on agricultural research by its creation of an economic environment that conditions the profitability and, therefore, the adoption of technology. Policy objectives can determine which crops, regions, and farmers are the main targets of the technology development and diffusion process. However, those responsible for production research, with their first-hand knowledge of production systems and alternative technologies for the circumstances of representative farmers, are in a favorable position for identifying limitations of agricultural policy (access to input and product markets, prices, and credit) and suggesting necessary changes. This is not to say that the results of production research determine agricultural policy, but that it is information which is necessary for making policy decisions. Figure 2 clearly shows the central role of production research in an integrated agricultural policy.

First, production research must be organized in such a way that it has some independence of operation or, in other words, that it be a formal part of national programs for development and diffusion. Countries that have undertaken production research have tried various plans: on-farm research as part of the crop research program, selection of specific areas where research methods can be strictly carried out, and running the entire institution according to this approach. The results of these experiences have contributed greatly to the methodological and institutional development of production research and the aiming of that research at farmers' needs. They have helped identify important ways of increasing the effectivity of agricultural research as a whole, as well as developing methods specific to production research.

Second, its operative independence must in no way isolate production research from basic research on experiment stations. If that happens, the technical assistance program will find itself in difficulties. Since production research is carried out on farmers' fields, often far from experiment stations and with its own schedules and needs, it is advisable that logistic support for the production research team not be based at the experiment station. Such needs as gasoline, expense accounts, spare parts, and inputs should be handled by an independent coordinated unit. It is preferable that experiment station support be in the area of technical assistance.

Most institutions for development and diffusion have committees for evaluating research results at the end of each cycle. These evaluating groups should include both experiment station researchers and members of the production research team, with a balance between the two so that the objectives and methodology of both programs are maintained.

Third, there is a critical mass of personnel and support without which production research cannot successfully

operate. If a two-person team is necessary to carry out the job in a specific area and produce effective results, one person will not achieve one-half of those results; unfortunately, research does not work that way. At the farm level, constant discussions need to be held on problems, results, and opportunities, and they cannot await a special visit or a trip to the experiment station. Also, there is a certain amount of experimental work that has to be done before arriving at valid conclusions. When the production research team is below minimum, there is the risk of ending up with trials but no results.

Fourth, whether the extension services have their own organization apart from the research institutions or not, a formal arrangement is necessary if extension workers are to work full-time and with sufficient support with the production research teams. Though production research methodology is important in the professional development of extension workers, it must be backed up by effective institutional arrangements. Without the participation of extension, the effectiveness of the production research team will be severely limited and the time needed to place alternative technologies in the hands of farmers greatly increased.

Research Structure and Incentives

Considering the number of improved technologies effectively adopted by farmers, the experiences of countries that have initiated production research are generally encouraging when compared with the results of conventional development and diffusion programs. However, the feeling seems to remain that the implementation of production research is costly. It is true that the major part of the work takes place in the field, and the teams live in the areas in which they work. There is always the real risk that some trials will be lost as a result of the same natural circumstances that confront the farmer. Also, expenses for such necessities as travel, expense accounts, and inputs increase and put still more pressure on the budgets of technology development and diffusion institutions.

This situation has sometimes caused bad feeling among experiment station researchers and some administrators who overlook the opportunity costs of resources held as fixed capital in the experiment stations.

Accepting the impact on adoption that the early work in on-farm research has had, it is necessary to consider whether the process has been efficient in terms of costs.

A search of the literature has revealed only one formal study where an attempt was made to measure strictly the cost efficiency of production research: Martinez and Sain (1983) analyzed these topics using the research experiences of IDIAP in Panama as a case study. They examined the benefits (adoption-impact) and costs (investment by the government) associated with the methodological innovation of on-farm research as an essential complement to traditional agricultural research. The rate of return on the investment required for implementing on-farm research in the study varied between 119 and 325%, depending on the areas being considered. Even in the worst of cases the rate of return was above the opportunity cost of capital and was comparable to that of other important agricultural technology developments. Although more studies of this type are needed, current evidence would

indicate that the method not only brings suitable technologies to the farmer, but also is efficient in terms of costs and time required for the process. Presuming that the value and cost efficiency of production research is reasonable, and that its incorporation into the process of technology development and diffusion is advisable, some aspects of the research structure and incentives may call for certain modifications.

A distinct characteristic of production research, as presented in this work, is the emphasis that is placed on representative farmers as targets of the process of technology development and diffusion. This approach is a change in traditional thinking on agricultural research. Traditional research has been based on problems emphasized by the professional disciplines, a consequence of the training that has been received by the researcher, principally at the graduate level, and the incentives that motivate them.

The incentive mechanisms within public institutions do not encourage researchers to act as instruments for extension of research results. This role is usually assumed by the private sector (agribusiness) in developed countries, and is only beginning to appear in Latin America. The incentives within research institutions in Latin America tend to stimulate professional contributions through the publishing of research results, taking part in professional organizations and the training of others within the same discipline (Winkelmann and Moscardi, 1979). In this way, traditional disciplines have had great influence on methods and the evaluation of personnel for promotion purposes. The result is that technology development and transfer has been primarily motivated by professional interests and, therefore, often has been irrelevant to the needs of representative farmers. There is no doubt as to the value of contributions made as a result of the above situation. However, if they are to be translated into benefits for the farmer, the structure of the process of development and transfer must be modified so that, at least for some personnel, institutional incentives will encourage contributions to representative farmers, and mechanisms will be established for facilitating production research.

Conclusions

Production research on farmers' fields is seen as an activity destined to bring together the environment in which farmers' decisions are made, the conventional process for technology development, and agricultural policy. Its ultimate objective is to increase the efficiency of agricultural research and focus it toward fulfilling the technology needs of representative farmers. The farmer is the primary target of production research, and the consideration of his natural and socioeconomic circumstances will make possible identification of problems and research opportunities and development of suitable alternative technologies.

The experimental phase, which is carried out on farmers' fields under their production circumstances, assures the identification (with the farmers' cooperation) of the alternatives to be subjected to verification and extension. The system gets feedback from studies and findings of experiment stations, and uses it for designing on-farm trials for the next cycle and suitable extension strategies.

The scope of production research that is presented here directs research at specific areas and generates alternative short-term technologies that are relatively simple. The limited resources usually available within national programs and the farmers' adoption process justify this approach. This suggests that the most efficient method identifies a few priority research opportunities within the farmers' production systems and then initiates the development and extension process.

In spite of new and encouraging experiences and the methodological developments resulting from them, research institutions still have a considerable number of problems to solve in adopting new programs.[3]

Current work will guide decision making in these areas and, at the same time, will adapt the process according to resource availability and institutional maturity within the various national programs. It is hoped that the considerations of methodological and institutional aspects covered in this paper will contribute to shortening the transition period for arriving at a greater efficiency in agricultural research in the various countries of the American continent.

3 For example, what type of scientists and training are required for research teams, who or what units should be responsible for recommendations, how new activities fit into existing institutions and how incentive mechanisms can be changed to motivate research personnel.

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Comment

Enrique Ampuero*

I find Dr. Moscardi's paper on the role of production research as a basic part of the technology generation and transfer process very interesting. My comments will link his paper to the experience I acquired during the establishment of this type of program at the National Agricultural Research Institute (INIAP) in Ecuador, as well as to my impressions of Latin American national research systems, with which I am in contact because of my work with the Inter-American Development Bank.

I agree with Dr. Moscardi on the importance of on-farm research as a step in the process of generating technologies which will respond to farmers' circumstances and needs. I also concur that on-farm research complements research carried on at experiment stations. It should be noted that traditional research covers on-farm research in the region. Usually this type of research is biological and springs from the researcher's perception of farmers' problems. Sometimes his perceptions do not correspond to specific local needs because he has not had enough contact with farmers and the problems that affect farm production. In this case, the technology generated is not useful because it does not satisfy priority needs and is therefore not adopted by the farmers.

This is the type of experience we had during the establishment of a production research program (sponsored by CIMMYT) in Ecuador. The purpose of the program was to generate technologies which would be adequate to the circumstances of poor small farmers in the Ecuatorian Range, where maize is a basic food product.

The worst difficulty was the institutionalization process of the program, since it required joint action by biology researchers, economists, and other support disciplines. Setting up a multidisciplinary group presents several problems: (a) some researchers have no interest in on-farm research because of the risk it implies; (b) sometimes it is not possible to obtain reliable data due to loss of land and high variation quotients, and (c) the cost of transporting personnel to areas that are far away from the experiment station adds to the financial burden.

Another basic aspect is placing on-farm research programs within the institutional structure, which is generally organized by products or by support disciplines. This type of organization results in fragmented activities which hinder interdepartamental coordination and, hence, the solution of problems that affect production. Some countries, such as Panama, have established technology transfer departments to carry on on-farm production research.

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Because of the type of activities production research programs carry on, staff is sometimes required to live on-site. In this case, the institution should carefully select staff members and give them additional incentives, as does Ecuador's INIAP. Personnel assigned to production research should have housing that is comparable to that of experiment station researchers, as well as equal opportunity for training and promotions within the institution.

Some research institutions in Latin America have made production research part of their strategy, as for example, Guatemala's ICTA, Panama's IDIAP, El Salvador's CENTA, Mexico's INIA, Ecuador's INIAP, etc. Other Latin American countries have had serious difficulty in establishing this type of program due to budget limitations. Finally, some institutions doubt the effectiveness of on-farm research and point out that it is costly and very risky.

One interesting aspect brought out by Dr. Moscardi is the role of production research in improving linkage and coordination of the researcher and the extension agent with the farmer. This linkage is usually very weak, though production research programs can strengthen it through the joint participation of researchers and extension agents in carrying out surveys to identify production problems, conducting on-farm research and assessing its results, and making recommendations. Within this context, personnel training plays a fundamental though complementary role. Training in industrialized nations is becoming more and more specialized and therefore sometimes does not produce what our countries need: agronomists with broad, solid training for identifying problems and finding practical solutions. With this objective in mind, training programs for people who will work in this field have been organized with the active cooperation of international centers.

I wish to point out that the Ministries of Agriculture, Planning, and Rural Development as well as the farmers themselves have widely accepted production research programs. There is a gradually growing demand for these programs, although it sometimes exceeds the capacity of research institutions.

Feedback from on-farm research programs is used to orient research at experiment stations so that it responds more effectively to farmers' circumstances and needs. In this manner, research project design is based not only on the researchers' perceptions of problems, but also on the continuous flow of data from on-farm trials.

Dr. Moscardi's paper clearly points out that the success of a production research program depends on the support of the various programs at the experiment stations, as well as on

technical information and results obtained from them. In view of the budget limitations at research institutions, on-farm research is a means of finding short-term solutions that can be transferred to farmers, as opposed to longer-term research programs that produce technological innovations.

Although some countries are already using the methodology that Dr. Moscardi describes here, there is still not enough information on the cost/benefit ratio of production research programs to compare them with other alternatives used by research and transfer systems for agricultural technology.

Lionel Richard*

I wish to congratulate Dr. Moscardi for having clarified the role of on-farm investigations and indicated the means to carry them out in the general process of economic development. It is indeed becoming more and more evident that on-station research has not yielded the expected dividends, at least in developing countries. As far as short-term benefits are concerned, the agricultural profile now calls for a completely new approach which considers basic development as the goal to reach. This suffers no delay, the greatest urgency being that the economic situation must not deteriorate any further.

A rapid analysis of Dr. Moscardi's presentation reveals that the author has touched base on a number of issues while ignoring completely certain aspects of a problem which varies according to the systems involved.

The author views on-farm research as a complement of traditional experiment station activities. On the contrary, the solutions sought on-station indicate that a first phase has been covered and that more advanced studies are required. It is perhaps a question of semantics, but I would rather look upon the cooperative actions in the farmer's field as the first steps leading to the pursuit of on-station investigations.

Dr. Moscardi has rightly stated that this research with the farmer, for the farmer and, oftentimes, by the farmer aims at delivering scientific and technological inputs to solve priority problems by means of appropriate recommendations.

These recommendations too often meet with the farmer's resistance or outright rejection because they do not fulfill a defined need, although it has been said that reluctance to change might be the cause of the failure of proposals.

In the long run, the reasons for adopting on-farm research might be more psychological than technical due to the fact that participation enhances understanding and facilitates better communication, if not a smoother transfer.

In many instances, the conceptual framework perceived by technicians goes beyond the impulses that motivate the farmer in search of a better life. One should not forget that the socioeconomic considerations that technically justify the need for investigation are no part of

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the small farmer's way of thinking. These attitudes are rather our responses to the fulfillment of our own demands, facing a situation of shortage. The paradox comes to light when one seeks a true definition of "dominant governing groups". It seems to me that the silent majority, represented by the small farmers in real control of the production chain, is the true governing group, in so far as their outputs govern the whole society's well being.

It should also be emphasized that the economic policy of an underdeveloped country does not initiate a demand for technology linkage; rather, the latter dictates the shaping up of that policy, so that it becomes a seasonal exercise instead of being the result of an integrated plan. On the other hand, if one does not expect the generation of technology to create a demand for it, then it appears that the usual criteria for choosing a field of activities do not apply, and that investigation should be tailored to the needs expressed, not perceived. It would therefore appear more convenient, in the light of the circumstances prevailing in the Third World, to divide the technological process into levels different from those expressed by Dr. Moscardi.

I would suggest:

1. The linkage between society—that is, farmer's society—and real demand for technology. This level manifests itself when production constraints can no longer be eliminated by traditional practices.

2. The linkage between the economic situation and technology generation. This level appears after priorities are identified and when an improvement seems within reach.

3. The linkage between technology application and development. This level is reached only when evidence of improvements introduced by the alternative proposed leaves no room for risks.

The components of the methodology for technology development and transfer are of course the results of farmers' circumstances analysis. Since each case presents its own peculiarities, it is obvious that no general rules can be set *a priori*. Further, the real influence of private organizations on technology development remains somewhat obscure, since their policies confine them to taking advantage of advances worked out by public institutions. They do complain about the lack of this and the absence of that, but their sense of profit makes them real scavengers who harvest what they have not planted.

In reviewing the methodology of on-farm research, the author has set forth five concepts which, in a sense, represent an implementation plan. However, instead of suggesting the idea of "production-research", it would seem more appropriate to work around the concept of "research-development" or "research-action", which from the outset identifies production constraints, along with factors that can be controlled in a relatively short term, because time is essential. The second

step consists of an in-depth analysis of the production system itself to study the logic behind the combination of crops, animal production and agronomic practices. Biological and socioeconomic surveys that would open the way to a clear definition of alternatives could be included. Finally, after the economic returns prove to be worth the risk, and when there is no spontaneous adoption, demonstration and transfer close the cycle of investigation.

In studying economic circumstances, the author failed to stress the importance of land tenure. Some recommended practices might not appeal to a tenant farmer who shares the benefits with the owner. We are then confronted with the obligation of establishing two sets of practices which unfortunately might have to be implemented within a limited area. Further, the size of the land under consideration might be another factor of policy modification likely to introduce conflicts while applying the results.

There is no comment to be offered as regards the diagram for the on-farm research program. The framework proposed seems to cover the most important topics; any addition or subtraction would only complicate matters.

When we come to the aspect of operation and institutionalization, it is necessary to abandon some of our paternalistic attitudes. We really have to come down to earth to realize that even an ill-equipped experiment station is far better than a regular farmer's field. We also should be aware of the fact that technicalities are not the answer to a weakness in technology and that a simple approach is more likely to be adopted than a complex series of scientific solutions. This in turn implies a difficult task for the researcher and the extension agent, for not only do they see the same problem in a different light but quite often manage to be off-target in their proposals. All in all, this may be a reflection on the efficiency of our extension services which still have the old attitude of sitting and waiting for the materials to be brought to them after the hard legwork has been completed. The necessities of on-farm research require that extension be present before, during and after research activities because survey facilities, as well as the structural network for follow-up, are vested upon them. More dramatic is the communication gap between the extension agent and the farmer. So long as it remains unbridged, the very work of the researcher is in jeopardy.

On-farm research as a link in the generation and transfer of technologies should be viewed as a condition *sine qua non* of changes in the rural world. It is a prerequisite of progress. All things considered, the real difficulties stem from the weaknesses of the research system suffering from a lack of adequate management, proper guidance, and human and financial resources.

In the last section of his presentation, Dr. Moscardi deals with the structural characteristics of an institution and the need for change in the incentives that can contribute to the development of the process. Despite encouraging experiences, the author believes the implementation of production research is costly. Personally, I would venture to say that on-farm research is cheap compared to on-station investigations. Furthermore, it seems that the need for change in the incentives is a bit premature in as much as actual experience points to a smoother acceptance brought about by closer contacts and appropriate adjustments while the work is still going on. The changes required address themselves to the formulation of procedures that would allow simultaneous work on different components of the production system so that the time spent on one crop could well serve to take care of other crops involved.

Development of Human Resources for Agricultural Research in Latin America

Eduardo Casas Diaz*

Introduction

Latin American governments face innumerable difficulties in creating and enforcing coherent and feasible development policies that assign an adequate place to rural and agricultural development. In many cases, they have inherited a structure designed for maintaining law and order, an organization to collect taxes and furnish income, as well as medium and long-term plans that give meaning to the governing function. Nevertheless, Latin American administrations frequently encounter considerable economic, social, and political difficulties. The best talent is required to solve or at least confront these problems, but there is an acute shortage of competent personnel at all levels of government.

In the final analysis, development objectives of Latin American governments are generally directed at improving the lot of the mass of low-income population. Most of this population lives in rural areas and depends on agriculture, though this activity does not furnish a decent standard of living, but just enough for subsistence.

The world of tomorrow, however, will be different and better as a result of scientific and technological advances. Thus the aim of scientific and technological activity is not so much improving yesterday's work, as achieving science and technology that will offer a better future to the present world. Scientific and technological knowledge should be subject to educational processes in order to ensure its permanence and future use. More concretely, developing nations should organize medium and long-term programs for training personnel to create, disseminate, and apply knowledge.

Basic Framework

In the agricultural sector, science and technology will play an important role over the next few years in expanding agricultural production. In order to use this knowledge correctly, it is necessary to develop and establish the modes of education, training, and technical assistance that will guarantee the adoption of advances by the farmer.

Latin America today is the product of two distinct cultures: that of European colonialist countries (Spain and Portugal) and native American culture. Colonialist countries established basic cultural traits as well as the social, economic, and political structures of the cities. This resulted in a dual organization of society and an economy oriented toward the exportation of basic products. With the exception of Argentina, Chile, and Venezuela, the region had dependent regimes where native hand labor played an important role.

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The development of modern science was simultaneous to the colonization process that began in the second half of the sixteenth century. As a result of the isolation and control that Spain and Portugal imposed upon their colonies, Latin America was unaware of the scientific progress in European countries, particularly in the second half of the eighteenth century. This isolation had a profound influence on Latin America's development as a region that is scientifically and technologically dependent. In spite of the fact that today it has outstanding scientists, prestigious research institutions, and excellent educational institutions, it has not been able to establish a system to promote the development of the primary sector.

On the other hand, Latin America has deep agricultural roots that go back to precolonial times, though the strong influence of the colonizing countries forced creative work into a structure that was foreign to the region. Today this phenomenon is even more evident as a result of imposed production and consumer patterns from industrialized countries. Thus the basic concept of agricultural research should be reviewed to see if it is an adequate means of generating technology that is appropriate to the cultural and environmental situations of the region. Transfer mechanisms should also be analyzed and the elements for applying technology in productive programs should be identified.

In addition to scientific and technological efforts, the region will have to expand its agricultural frontiers to satisfy food demands. It is estimated that Latin America could go from 162 million hectares under cultivation in 1980 to 270 million by the end of the century. The latter figure represents 39% of potential farm land (a total of 693 million hectares). It could also increase its irrigated farm land from today's 14 million to 19 million in the year 2000, which is only 38% of the land that is potentially irrigatable (50 million hectares).

This task should be started after an extensive research program to avoid possible soil degradation when lands are opened to cultivation.

It must be remembered that man and his socioeconomic environment are the elements of technology generation, transfer, and application. Thus Latin American countries' need for raising food production makes traditional subsistance farming useful, for the small farmer is indispensable and must be encouraged to help in this process. Due appreciation of his knowledge and his cultural and socioeconomic values is the basis for getting him to participate.

The following is a breakdown of the institutions that are involved in this process: 1) research institutions; 2) technical assistance institutions; 3) institutions that supply the farmer with services such as credit, farm insurance, fertilizers, pesticides, etc. Of the many relevant aspects that can be discussed, two are important: first, the above mentioned institutions in most countries are independent of each other, which is inefficient. Secondly, academic institutions that offer professional and practical training are institutions that generate scientific knowledge and transmit it through the educational process, and could therefore make a study of the whole process.

Advanced Education

Advanced education is generally known as third level education; thus the concept includes university and non-university training, as well as undergraduate and postgraduate studies. There is no universal criterion that distinguishes between university training and non-university training in third-level education. This division in the various countries of Latin America depends on legal and administrative decrees that are not uniform.

In third-level education, the differences in enrollment do not depend on the length of professional training; the main problems are the different definitions of what constitutes a university. In some countries such as Brazil, an institution must have three schools to obtain university status, while in other countries, status is accorded *ad hoc* and no uniform requirements exist for all the units of the system. Because of this situation, small schools with a few hundred students and mega-universities with more than 100,000 students (the National Autonomous University of Mexico, the University of Buenos Aires, etc.) coexist under the name of universities.

Besides the quantitative aspect, quality must also be considered. Some Latin American universities have important scientific research centers, but in most of them research simply does not exist or is the minimum required for professional training. Some universities have faculties with high academic standing (master's and doctor's degrees) while the faculties of many others not only have not published research papers in journals or books, but their educational level is that of a secondary education institution.

A review of professional training offered by Latin American universities would only supply information about one of a university's basic functions (that is, educating advanced level professionals), but would tell us nothing about its scientific level. Supposedly the scientific level determines whether an institution is a university or not, for scientific achievement means that the institution is a center that creates and disseminates science; in other words, it endows society with new knowledge that other institutions cannot produce.

Classifying Latin American universities according to the degree of scientific development could be based on indicators such as libraries, laboratories, original scientific publications, faculty educational level, etc.; nevertheless, it would be a very complex process. For this reason, expanding the educational level to fourth level (which comprises postgraduate studies only) is beginning to be considered an indicator of the evolution toward a scientific university.

The application of uniform criteria is very difficult. University tradition in various Latin American countries dictates that undergraduate training be expanded to include postgraduate studies; in contrast, Anglo-Saxon countries have tended to separate these levels clearly and to reduce the length of undergraduate work in time and academic content. The relatively few postgraduate centers in Southern Cone countries, for example, are not a sure indicator of a lack of this level of education, nor of a lack of scientific development policies, for these nations have established research programs within traditional universities and have taught postgraduate courses at the undergraduate level.

On the other hand, we should mention that in countries where there has been an accelerated expansion of university systems accompanied by an obvious deterioration of the educational level, postgraduate programs often are at the undergraduate level academically. This tends to compensate for the deficiencies at basic academic levels and establishes new levels of accreditation that will make the specialist more able to compete in a keenly contested job market.

Some nations, such as Brazil and Mexico, have consistent policies and authentic postgraduate education. This is due to the fact that government organizations have largely controlled its creation and have demanded high standards of the faculty, in the equipment, and in granting scholarships to scientists that seek high level scientific and technological training.

In presenting the purely quantitative aspect of third level education, we will cite some indicators, with 1980 as the base year, in order to make inter-and intraregional comparisons. Total population on the American continent came to 610 million in 1980 (Table 1); 58.8% of it was distributed in Latin

Table 1. Third-level training in America; students per 100,000 inhabitants, 1980

Region	Population (thousands)	Enrollment	Student/ 100,000 inhabitants
Northern	117,718	1,452,555	1,234
Andean	73,624	1,204,366	1,636
Southern	167,166	2,038,764	1,220
Latin America	358,508	4,695,685	1,310
United States	227,640	12,096,895	5,314
Canada	23,941	888,444	3,711
North America	251,581	12,985,339	5,161

Source: Based on data contained in the 1983 Annual Statistics Report published by the United Nations Education, Science and Culture Organization (UNESCO), London, England, 1983

Note: In the tables that appear in this paper, Latin America was divided into three main regions:

Northern Region: Costa Rica, Cuba, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Puerto Rico, Trinidad Tobago, Barbados, Bermudas, Dominica, Grenada, St. Kitts-Nevis-Anguilla, St. Lucia, and St. Vincent and the Grenadines

Andean Region: Bolivia, Colombia, Ecuador, Guyana, Peru, and Venezuela

Southern Region: Argentina, Brazil, Chile, Paraguay, and Uruguay

America. Of the 17.7 million students registered in third-level education programs on the whole continent, 26.6% live in Latin American countries. These ratios express significant differences between the number of students per inhabitant in North and Latin America. Thus, in 1980, for every 100,000 inhabitants there were 5,161 students in North America and 1,310 in Latin America.

There are also notable differences among Latin American countries in regard to the number of students per 100,000 inhabitants. On one end of the spectrum, we find nations with high ratios such as Puerto Rico (3,773) and Ecuador (3,162) and on the other, low-ranking countries such as Haiti (82), Guyana (295), and El Salvador (350).

Another indicator of third-level education is the student/teacher ratio (Table 2). In 1980 teaching staff for the whole American continent was 846,200, of which 46.9% were employed by Latin American institutions. This significant number of teachers (397,000) in third-level education presents the possibility of scientific differentiation and mechanisms which will allow them to be full-time teachers. The number of third-level professors in the largest countries in the region is outstanding, for Brazil has 129,000, Mexico has 78,000, and Argentina has 46,000. Less-populated countries that have more advanced educational systems also register high numbers of teachers: Venezuela, 28,000; Colombia, 27,000; Peru, 17,000.

Nevertheless, training programs for teaching staff are scant as a result of the few postgraduate programs in education. Not many countries have established norms for recruiting teachers; Brazil and Mexico adopted the North American model that demands a master's degree for certain academic positions and a doctor's degree to teach and do research at the postgraduate level. It must be pointed out that authorities in most countries are aware that the enormous expansion of the universities is taking place without

Table 2. Third level training in America: faculty and enrolled students, 1980

Region	Faculty	Enrolled students	Student/ teacher ratio
Northern	115,787	1,452,555	12.5
Andean	88,509	1,204,366	13.6
Southern	192,498	2,038,764	10.6
Latin America	396,794	4,695,685	11.8
United States	395,992	12,096,895	30.5
Canada	53,434	888,444	16.6
North America	449,426	12,985,339	28.9

Source: Based on data contained in the 1983 Annual Statistics Report published by the United Nations Education, Science and Culture Organization (UNESCO), London, England, 1983

adequate teacher training. In quantitative terms, the teacher/student ratio of 12 to 1 seems adequate for Latin America, in comparison with 29 to 1 for North America.

In 1980, public spending for education in general was 7% of the gross national product in North America and 3.9% in Latin America (Table 3). This expenditure was also 18% of total public expenditures in North America and 14.5% in Latin America. The differences are very serious both in absolute and relative terms. There are also notorious differences in the efforts of various Latin American countries in regard to education. Some countries channel a great proportion of their financial resources toward education: for example, Costa Rica and Cuba spent 7.8% and 7.2% of their gross national product, respectively, as well as 22.2% and 30% of their total expenditures.

In North America third-level education absorbs 35.4% of public funds allotted to education, while in Latin America it absorbs 24.5% (Table 3). There are great extremes in Latin America: while Venezuela spends 34.6% of its total public funds for education on third-level training, Peru just spends 3.1%.

From the beginning of the 1960s, Latin American universities have made systematic efforts to encourage students to enroll more in technical fields such as engineering and agronomy and less in the traditional professions such as law or medicine.

In Latin America, advanced agricultural training programs have tended to be based on the concept of technology as the moving force of production, and production as a strictly technical problem. In broad terms, specialized programs have been developed in edaphology, phytotechnology, zootechnology, plant and animal pathology, irrigation, statistics and systems, agroeconomics, agricultural education, and, currently, ecology.

Table 3. Third-level training in America: public spending, 1980

Region	% of the gross national product	Total spent on education as % of total government spending	% spent on third-level training
Northern	4.4	14.3	23.1
Andean	4.0	19.2	19.3
Southern	3.5	11.8	28.5
Latin America	3.9	14.5	24.5
United States	7.0	18.1 (1975)	36.0 (1979)
Canada	7.7	17.3	27.4
North America	7.0	18.0	35.4

Source: Based on data contained in the 1983 Annual Statistics Report published by the United Nations Education, Science and Culture Organization (UNESCO), London, England, 1983

On analyzing these training programs, one gets the impression that most of them overlook social and cultural problems of the rural sector. In advanced-level agricultural institutions it is common to find that students who should be dedicated to improving the poorest rural social strata spend four or five years away from the environments they are supposed to work in.

In spite of serious problems, some progress has been made in orienting and organizing advanced education institutions. The real increase in enrollment, the proliferation of academic units, the diverse opportunities for teachers' training, the academic level of the teaching staff, the availability of scientific, experimental, and trial equipment and materials, the broadening of educational programs (by including social science subjects, for example), and, finally, the increased opportunities for specialization are the main advances in high-level agricultural education.

One factor that indicates the level of advanced agricultural education is increased enrollment, which in 1980 was approximately 234,000 students (5.1% of total advanced education registration) (Table 4). Most of this enrollment was in the Northern Region (47.6%); the Andean Region had 28.4% and the Southern Region had 24%. The Northern Region also had the highest percentage of the total advanced education enrollment (8.4%), while the Andean and Southern Regions had 5.5% and 2.8% respectively.

Table 4. Third-level training in America: students enrolled in agriculture,[a] 1980

Region	Enrolled students Total	Agriculture	% in agriculture
Northern	1,318,188	111,168	8.4
Cuba	151,733	14,566	9.6
Mexico	897,726	86,182	9.6
Andean	1,204,366	66,435	5.5
Peru	306,353	23,985	7.8
Southern	2,038,764	56,115	2.8
Argentina	491,473	25,065	5.1
Brazil	1,345,000	22,865	1.7
Latin America	4,561,318	233,718	5.1
United States	N.A.[c]	N.A.	–
Canada	888,444	17,069	2.0

Source: Based on data contained in the 1983 Annual Statistics Report published by the United Nations Education, Science and Culture Organization (UNESCO), London, England, 1983

[a] This includes agronomy, forestry, and fishery training
[b] This does not include Dominican Republic, Puerto Rico, and Trinidad Tobago
[c] N.A.: Not available

There are marked differences in advanced agricultural education among Latin American nations; for example, in the north, Mexico has 77.5% of the enrollment and also the highest percentage of agricultural education enrollment as compared to total registration in advanced education (9.6%). Cuba also has a considerable proportion (13.1%) of the enrollment in the Northern Region, as well as a 9.6% ratio of agricultural education to total advanced education enrollment.

In the Andean Region, Peru's share of the enrollment is 36.1%, and its enrollment in agriculture is also noteworthy (7.8% of its total enrollment). In the Southern Region, Argentina has 44.7% of the enrollment and the percentage of agriculture enrollment in relation to total enrollment is 5.1%. Brazil's enrollment is 40.7% and in 1975 the ratio of agricultural registration to total enrollment was 1.7%. In that same region, Uruguay had the highest agricultural registration in relation to total advanced education enrollment (9.4%).

Another indicator of the level of advanced agricultural education is the academic standing of its teaching staff and, to a certain degree, its postgraduate programs. Table 5 contains information for a partial diagnosis of the quality of postgraduate programs and their teaching staffs. It must be noted that this information is incomplete, for the estimated number of higher education institutions in Latin America is 350 and Table 5 includes only 141; of these, 139 have undergraduate programs and 42 offer postgraduate training. Enrollment at the 141 institutions was 94,200 students with a faculty of 10,444 teachers, that is, 9 students per teacher. Though these data only cover 40% of Latin American enrollment, they are quite useful, for they give an approximate picture of the quality of advanced agricultural education in those countries.

To illustrate the make-up of the teaching staff at these institutions, Table 6 shows that out of 10,444 teachers, 72.4% are employed full-time. This indicates great progress in quality, for we can suppose that the faculty channels feedback from research into its teaching activity. A clear result of the institutions' efforts to better the academic level of their faculties is the fact that 61.8% of the full-time staff have bachelor's degrees, 24.3% have masters, and 13.9% have doctor's degrees.

A regional analysis would be rather vague due to the lack of data on certain countries. We will therefore focus on individual nations that have made the greatest progress in training high level teaching staffs.

In the Northern Region, Mexico has 2,052 teachers, 61% of whom are full-time. Of this percentage, 67.4% have bachelor's degrees, 23.4% have master's degrees, and 9.2% have doctor's degrees. In the Andean Region, Colombia has a roster of 978 teachers, 78.6% of whom are full-time professors. Of the full-time staff, 37% have bachelor's degrees, 35.2% have masters, and 27.8% have doctorates.

Table 5. Third-level agricultural training[a] in Latin America: institutions, enrolled students, and faculty, 1980

Region	Institutions	Training level		Enrollment		Faculty					
						Bachelor		Master		Doctor	
	No.	Undergrad	Postgrad	Undergrad	Postgrad	F.T.[b]	P.T.[c]	F.T.	P.T.	F.T.	P.T.
Northern	47	45	12	34,356	887	1,486	799	394	260	170	75
Mexico	31	30	10	27,060	744	843	594	292	140	115	68
Andean	36	36	8	19,393	687	1,207	290	471	151	158	41
Colombia	14	14	2	9,423	496	579	128	99	52	91	29
Southern	58	58	22	36,944	1,933	1,981	1,108	974	112	720	47
Brazil	30	30	15	23,141	1,744	886	269	845	64	666	31
Total	141	139	42	90,693	3,507	4,674	2,197	1,839	523	1,048	163

Source: Based on data contained in: Burton E. Swanson, *et al.* International Directory of Agricultural Education Institutions. Volume II: Latin America and the Caribbean, Bureau of Educational Research, College of Education, University of Illinois at Urbana-Champaign, 1981

[a] This includes agronomy, forestry, and fishery training
[b] F.T.: Full-time
[c] P.T.: Part-time

There is a total of 42 graduate programs at these institutions. In the Northern Region, there are 12 programs in three countries: Costa Rica (1), Mexico (10), and Trinidad Tobago (1). Postgraduate enrollment was 2.6% of advanced agricultural education. In the Andean Region, there are eight programs in three countries: Colombia (2), Peru (2), and Venezuela (4). The percentage of postgraduate enrollment was 3.5%. In the Southern Region there were 22 programs in three countries: Argentina (3), Brazil (15), and Chile (4). Postgraduate enrollment was 5.2% of total registration for advanced education (Table 7).

This quantitative and qualitative progress in higher education institutions in Latin America is one of the fundamental elements on which these nations should base their objective of raising the educational level of the rural sector.

It should be pointed out that though all the institutions involved in agricultural research (universities, schools, and colleges) generate knowledge and technology within specific sociocultural environments, these results have not been sufficiently diffused nor completely and exhaustively applied. For this reason, the first point that should be established is: the generation and transfer of knowledge is a continuous process that should not be divided operationally, administratively or organically. Everyone involved in research and technical assistance programs should be made aware of this.

Table 6. Third-level agricultural training[a] in Latin America: faculty structures, 1980

Region	Faculty					
				Full-time		
	Total	Full-time	Total	Bachelor	Master	Doctor
Northern	3,184	2,050	2,050	1,486	394	170
	(100)	(64.4)	(100)	(72.5)	(19.2)	(8.3)
Mexico	2,052	1,250	1,250	843	292	115
	(100)	(60.9)	(100)	(67.4)	(23.4)	(9.2)
Andean	2,318	1,836	1,836	1,207	471	158
	(100)	(79.2)	(100)	(65.7)	(25.6)	(8.6)
Colombia	978	769	769	579	99	91
	(100)	(78.6)	(100)	(75.3)	(12.9)	(11.8)
Southern	4,942	3,675	3,675	1,981	974	720
	(100)	(74.4)	(100)	(53.9)	(26.5)	(19.6)
Brazil	2,761	2,397	2,397	886	845	666
	(100)	(86.8)	(100)	(37.0)	(35.2)	(27.8)
Total	10,444	7,561	7,561	4,674	1,839	1,048
	(100)	(72.4)	(100)	(61.8)	(24.3)	(13.9)

Source: Based on Table 5

[a] This includes agronomy, forestry, and fishery training

The second point to emphasize is: the transfer of knowledge should include effective management structures in order to apply results as soon as possible. Effective management is focused toward bringing about political and executive decisions to collect financial, physical, and organizational resources for the adoption of knowledge within the specified level, space, and time. Training programs must make clear that the transfer of technology is indispensable so that students who have the aptitude, ability, and vocation to implement effective management practices will not only be made aware of the need for this fundamental aspect of the production process, but will also engage in it. The production process must adapt to the socioecological conditions, particular cultural values, and types of agriculture that are prevalent in the area. Pilot plans to define as finely as possible the restrictions and characteristics of adopting the production process will be necessary.

A certain time period is required for a new system to be adopted that is not always feasible in Latin American countries. This the result of high personnel turnover at the institutions responsible for this process; those in charge leave or their guidelines are modified. This brings us to the third point of synthesis: research and academic institutions are precisely the ones that should be responsible for initiating, carrying out, and consolidating this educational process.

Table 7. Third-level agricultural training[a] in Latin America: institutions that have postgraduate programs, 1980

Region	Institutions No.	Postgraduate enrollment as a percentage of higher agricultural training enrollment
Northern	12	2.6
Costa Rica	1	7.5
Mexico	10	2.7
Trinidad Tobago	1	25.0
Andean	8	3.5
Colombia	2	5.3
Peru	2	1.8
Venezuela	4	2.8
Southern	22	5.2
Argentina	3	0.3
Brazil	15	7.7
Chile	4	3.0
Total	42	3.9

Source: Based on Table 5

[a] This includes agronomy, forestry, and fishery training

Academic institutions work with scientific and technological knowledge and use it to train professionals who will in turn carry on research and educational activities. Academic, research, and technical assistance organizations are responsible for generating science and developing technology; in other words, they make up what A. H. Bunting of Reading University in England calls National Knowledge Systems.

The main components of such systems are: 1) the store of knowledge found in libraries, information centers, and in people's minds and memories; 2) research that broadens this store of knowledge through the generation of new knowledge; 3) the necessary means to prepare this knowledge for transfer (in other words, development, the phase in which technology is produced and tested); 4) the means for transferring knowledge, skills, and technology, as well as teaching how to apply it (in other words, formal university training, practice, and technical assistance); and lastly, 5) the practical means for applying knowledge or technology to specific purposes.

Research alone can progress very little without the other components of the system, or if these components do not transfer knowledge effectively. Therefore, the fourth point of synthesis is: it is absolutely necessary to unify the national knowledge systems of Latin American countries. I must point out that the Consultative Group on International Agricultural Research (CGIAR System) can make a significant contribution to this task. One must remember what has been repeatedly brought up in various discussion groups: in the long term, the CGIAR will be judged not by its contributions to the development of a particular crop, but by the number of agricultural knowledge systems that it will have helped to create.

This last point is particularly important because in most developing nations third-level agricultural education was established at the end of the colonial era when independence began. The oldest agricultural schools and colleges in Latin America have kept traditional academic patterns that do not satisfy modern needs; these institutions do not associate their academic programs to government efforts in agricultural research and development. Worst yet, if the third-level institution is eminently academic, there is a marked tendency to separate science education from technical training, which is detrimental to both fields. The establishment of strong links between the agriculture ministries and the universities is urgent.

If all these recommendations are put into practice, it will not be difficult to organize and establish a regional system that will allow for interaction, complementation, and mutual support of the different national agricultural systems in Latin America. Thus we arrive at the fifth point of syntesis: the unification of the academic and research institutions of each country under a national knowledge system will bring about the establishment of a regional network to facilitate the flow of information and organized team work.

Postgraduate College

The establishment of the Postgraduate College in Mexico was the result of a growing interest in raising the academic level of agricultural education in the mid 1950s. The establishment of postgraduate studies in agricultural science was possible thanks to nearly 20 years of continued work in agricultural research programs; during this time researchers were trained in foreign countries.

The Postgraduate College started with research and educational programs in four areas: Genetics, Soils, Entomology, and Phytopathology. Twelve professors and 23 students participated in these initial programs during 1959 and 1960. There were 23 courses and 71 research projects in field experiments and in the laboratory.

On January 4, 1979, 20 years after its establishment, the Postgraduate College became, by presidential decree, a decentralized public organization with its own legal status and capital. In 1984, when the College celebrated its 25th anniversary, it had educational and research programs under way in 11 centers at headquarters, 3 regional centers, and 2 interdisciplinary programs. In 1961, Botany was added to the original four fields (there is now a center dedicated to each); in 1962, Statistics and Calculus were added, as were Agricultural Economics in 1964, Irrigation and Drainage (now Hydroscience) in 1967, Agricultural Information Service (now Rural Development Studies) in 1968, Animal Husbandry in 1979, and Fruit Culture in 1984. The first regional center was established in Puebla in 1976 as the Educational, Research, and Training Center for Regional Agricultural Development (CEICADAR). In 1979, the Regional Center for Education, Training, and Research in Agricultural Development in the Humid Tropics (CRECEDATH) was founded in Tepetates, Veracruz and in 1980, the Regional Training Center for Arid and Semi-Arid Zones (CREZAS) was established in Salinas de Hidalgo, San Luis Potosi. The Forestry and Agrometeorology Programs are interdisciplinary and will become centers when they are consolidated.

In 1983, the College carried out its scientific and academic activities with a teaching staff of 334, of whom 92 had doctorate degrees and 83 had master's degrees in science. There were 405 postgraduate students and 300 courses were given at the master's and doctorate levels; 416 research projects related to different specialties in agricultural sciences were carried out.

At the Postgraduate College, postgraduate training is supported by research necessary to solve problems that demand new scientific knowledge. Therefore, descriptive, analytical, interpretative, and predictive research has its place within the academic programs. As for what, why, where, and how to research, research that focuses on practical problems is coordinated with basic research. Basic research is useful because it discovers unknown facts and furnishes information on which to base hypotheses and formulate theories and laws; it also clarifies or verifies the validity and nature of facts, and explains phenomena in a broad and integrated way. Thus it avoids utilitarian and technocratic pursuits and promotes a consistent program of development based on firm concepts of research as a human activity and as service to education.

The manner in which the College links its educational and research programs to rural environments is based on the following:

1. The role of agricultural training and research is fundamental to the definition of strategies that are appropriate to the diverse ecological, economic, and social conditions of each region and that promote agricultural and rural development.

2. It is necessary to understand how environmental, economic, political, social, and cultural factors interact and affect rural development processes.

3. Systematically organized knowledge is absolutely necessary for defining problems in agricultural and rural development.

4. Very possibly, the association of teaching, research, and operational activities will be consolidated in the rural environment. Service institutions and farmers that participate in rural and agricultural development are in charge of operational activities.

The basic characteristic of the Postgraduate College has always been its speed and flexibility in responding to the problems of the rural sector. When in the mid 1960s, agricultural production, especially rainfed production, collapsed, the College began a development program in the most backward sub-sector of rainfed agriculture. This program, which was called Project Puebla,[1] started in 1967 on 116,000 hectares in the State of Puebla where the main crop was maize. The following are the project objectives:

1. To generate technology that could be adopted quickly by farmers and which would substantially increase yields per unit of rainfed maize fields.

2. To design and implement a training program for extension agents in maize technologies. This program would include more profitable crops as the income of maize farmers increased.

In order to achieve these objectives, strategies were planned to include the participation of farmers, a group of technicians interested in the problem, and public and private institutions of the State of Puebla. They also included the generation of technology for farm production, diffusion of the results, timely and sufficient farm credit, adequate supplies of technical inputs, crop insurance, favorable product/input price ratios, farmer associations, and crop marketing.

In 1971, Project Puebla became the Puebla Plan and, in 1973, seven years after the program started, the Mexican Government established the National Agricultural Development Program for Rainfed Regions (PRONDAAT) as part of the National Agricultural Plan. This program applied the experience of the Puebla Plan, though it was necessary to train technical personnel to carry it out.

In 1974, the Secretary of Agriculture formally approved an agreement that was signed by the Postgraduate College, the National Agricultural Research Institute (INIA), and what was then General Headquarters for Farm Extension; these institutions agreed to carry out PRONDAAT in eight federal entities. The Postgraduate College was made responsible for training and was granted the necessary funds for establishing CEICADAR. CEICADAR also carries on projects for the 11 research centers based in Chapingo.

In keeping with CEICADAR's experience of the regional programs' potential contributions to agricultural and rural development in areas of rainfed agriculture, the College established CRECIDATH and then CREZAS.

1 During 1967/1973, the Postgraduate College and the International Maize and Wheat Improvement Center (CIMMYT) worked together on this project.

CEICADAR's experience was also the basis for the Temporal Districts that the Department of Agriculture and Water Resources operates and from which it directs its state and regional agricultural programs. The Postgraduate College is also responsible for Temporal District Number III in the State of Puebla; this makes possible the linking of its educational and research programs to operating programs.

For 17 years, the Postgraduate College has accumulated experience in working with operative institutions and farmers as an educational and research institution; the following are the result of this experience:

1. An educational institution carries on research in order to teach, and teaches in order to research, plan, implement, and assess regional agricultural development programs. Thus, the regional program is a means for understanding development processes and enriching educational programs with the knowledge it generates. Therefore, participation in the diagnosis and definition of strategies and objectives as well as in the implementation and assessment of a regional program is a means for achieving training objectives, never an end in itself. In practice, the means to get to know the nature, elements, interactions, difficulties, and alternative solutions of a problem are sought. For this reason, systematic information gathering is one of the most valuable contributions of an educational institution, besides making available an adequate ecological, economic, social, and political environment for training, teaching, and research.

2. An educational institution participates in the process carried out by operative entities and assists in production and productivity, and in increasing the income of rural communities. These are indicators of the effectiveness of strategies tested in the field. In this manner, the educational institution operates as a creative entity.

3. The educational institution is faced with a triple task in its efforts to achieve regional program objectives (planning and testing of strategies, training and information systems). First, it applies scientific methods in planning, implementing, and assessing a program; it thus tests the effectiveness of alternate strategies. Secondly, it demonstrates the effectiveness of a strategy according to the concrete objectives they achieve (increased production, productivity, income). Above all, its aim is to persuade farmers and institutions to apply research-generated knowledge.

Advanced agricultural education institutions, as part of the national knowledge system, will fulfill their social commitment to the degree that they improve rural environments. To achieve this, modifications in form and approach are attempted which would link training and research programs closely to farm and rural problems.

The College has the firm intention of creating an agricultural knowledge system; but beyond that, I believe it has made very significant progress. For instance, it has complete and up-to-date libraries and specialized information centers both at the College and at each one of the regional centers (in the arid zone, high plateau, and in the tropics). It gathers practical know-how, existing technology, and the wisdom of the farmer (mainly in Mexico) by different methods; the knowledge collected sometimes dates back to hundreds or thousands of years.

Postgraduate programs for obtaining master's degrees are established first, and later, as it becomes possible, doctorate programs are started. In Latin America, this has the advantage of a general training plan for conditions shared by all countries in the region (socioeconomic, environmental, ecological conditions, plus common ancestral roots and caste). The language problem is reduced or eliminated. Last, but not least, graduate studies in Latin America are more cost and time efficient, since a greater volume of information and knowledge is gained in a given period of time.

New approaches that improve efficiency and produce more and better trained professionals in the shortest possible time are being sought today. There is the idea of reducing student residency at the teaching institution and allowing thesis research to be carried out at their own institutions or places of origin.

Over time, as academic programs evolve, the task of transmitting knowledge is diversified; not only is third-level education imparted, but practical training, technical assistance, and farmer education are carried on through farm programs. Training should therefore be considered a permanent, integrated, and essentially cooperative process that tends to generate and transmit knowledge, aptitudes, and skills.

Conclusions and Recommendations

In Latin American countries the economic situation is pressing, for there is zero economic growth, high rates of inflation and unemployment, a heavy foreign debt, as well as increased population and food demand. The most urgent need, however, is to better the standard of living of farmers.

This objective demands political determination, financial resources, and organization, but above all, it requires well-prepared personnel, skilled farmers and technicians, and committed officials. This team will be responsible for advances in production and welfare.

In view of the clear priority to train professional and technical personnel and transmit knowledge and experience, a brief analysis was made of the educational structure in Latin America. According to this analysis, there is an ample range of academic institutions that are quantitatively and qualitatively heterogeneous but which can and should participate in the described tasks.

It is necessary to integrate research, technical assistance, and training activities through a national and international system. The experience of the Postgraduate College in Mexico proves not only that it is possible but also convenient to link academic training to practical field work. In this manner, academic institutions are incorporated into the system that carries on scientific work and supports formal programs aimed at granting academic degrees in specialized fields that solve problems in Latin America. On the other hand, practical training is promoted through programs that are applied in the fields.

Interdisciplinary teams of highly trained specialists are required to direct training efforts and in-depth studies on specific regional problems. This personnel not only carries on basic and applied research, but should have an understanding of technology transfer process and regional problems as well.

Here are some suggestions on the subject:

1. Each country should establish at least one rural development program to integrate the productive process, from the generation of adequate technology for the region, technical assistance, and the negotiation of logistical support for the annual or periodic production campaigns.

2. Rural development programs should last at least 10 years and an academic institution should be responsible for them. As a result, there would be direct participation of a select group of technicians and scientists as well as a close relationship between the university and the farmers. In this manner, feedback of real problems is available to the institution for the organization of pragmatic training programs. When a certain number of specialists has been recruited and the program has reached a certain degree of maturity, postgraduate training could be started and gradually broadened to fit local needs.

3. Each country should have a national knowledge system that includes information systems, documentation centers and libraries, universities and other educational institutions, research institutions and technical assistance services. The rural development program and the central coordinating institution could initially be the nucleus of the system.

4. The national systems should ensure adequate training at all levels according to local needs. Whenever possible, they should provide formal training, including the postgraduate level. At least part of the advanced training of more experienced personnel should take place in a foreign, though not necessarily developed, country. In some academic fields (for example, rural development) a basic part of postgraduate studies should be in another developing nation that is in a similar, but more advanced, situation. Technical assistance personnel should be an essential part of the system, for they link the various components of the system to the farmer.

   The system should also involve the farmers, not as a target objective, but as participants who have valuable contributions to make.

5. A basic part of the national agricultural knowledge system is the training of scientists, aimed at planning and assessing agricultural and rural development projects, as well as the administration of scientific activities.

6. Each country should have a specific budget allocation for a basic plan for establishing systems and an international agricultural knowledge network. In addition to organizing and gathering basic information, feasibility studies and the creation of strategic instruments for achieving concrete objectives within the specified time are essential.

7. Lastly, the most developed academic institutions in the region that have experience in rural development programs should be the ones to start training programs in other interested countries. International organizations should support these efforts and agreements should be established among beneficiary nations. It must be noted that the Postgraduate College has prepared technical teams for other countries of the region; nevertheless, a systematic, continuous training program has not been accomplished. Perhaps this objective could be achieved through adequate agreements and support.

Comment

Fernando Gómez Moncayo*

The countries that make up Latin America have a common origin: the fusion of European (Spanish and Portuguese) and native American cultures. This fact has given the region's socioeconomic development certain basic characteristics; hence it is feasible to unite the efforts and experience of all Latin American nations in overcoming the present barriers of underdevelopment.

One of the many elements that our countries have in common are the deep agricultural roots that are reflected in the economic importance of the agricultural sector. Most economic plans assign the sector activities that are essential for development. The most common ones are:

- Creating jobs.
- Producing raw material for industrial development.
- Producing food for the people.
- Generating foreign exchange for acquiring capital for industry.

All this implies that the sector should improve its efficiency, since there are usually limited physical (land, hand labor) and economic (credit, etc.) resources to bring about production increases at competitive prices through domestically generated or imported technological changes. In general terms, technological change in Latin America has been described as international transfer (especially from industrialized nations) of mechanical and chemical technologies (insecticides, herbicides, etc.) as well as biological technologies. Given that the application of these technologies varies according to environment, there is some independence at the local level. Imported non-native species have changed our countries' production and consumption patterns for those of developed, technology-exporting nations.

Autonomy in technological change is possible thanks to the development of local research in aspects that have comparative advantages in relation to developed nations, in other words, biological research activities.

Being as Latin America will have to satisfy the food and socioeconomic needs of 472 million people in 1990, and of 601 million in the year 2000, the basic concepts of agricultural research as the principal means of generating technological change have to be examined. These concepts should be the result of technology which is adequate to our environmental, cultural, social, and economic situations. The mechanisms and systems for technology transfer (including factors that determine the adoption of technology) should also be analyzed in order to set up an adequate and dynamic system for technological change. In each country, the success of this change depends both on political decisions that stimulate the generation, transfer, and application of technology and on training scientific personnel needed for these activities.

The process of technological change is closely linked to the scientists dedicated to technological change activities, since the extent of change and how fast it occurs depends on the amount of personnel and its academic level, as well as on the education and production infrastructures. Therefore, the relationship between research and education is defined as follows:

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"Problems and limitations generate research projects that produce new knowledge which is transmitted through academic or technical institutions. New knowledge modifies production systems and identifies new problems and limitations, and the cycle begins over again." For this reason, it is important to have dynamic research and educational systems that are constantly in touch and closely linked to the environments in which they operate.

I wish to point out some aspects that limit technological change in Latin America:

- Lack of national or regional systems that integrate agricultural knowledge.
- Lack of a uniform classification of educational institutions.
- Insufficient physical, financial, and qualified human resources.
- Lack of coordination among the institutions that carry on these activities.

For these reasons, I agree with Eduardo's proposals: first, that the educational level in Latin American countries, especially of people dedicated to research and education, be increased, and, secondly, that a strategy for consolidating this task according to the available conditions and resources be worked out.

In order to use scant financial resources more efficiently, and make the most of conditions prevalent in Latin America, it is necessary to:

1. Create in each country a national knowledge system that will unite research, transfer, and educational institutions.
2. Define norms to reduce the differences in educational levels among Latin American countries.
3. Strengthen educational and research systems in the region.
4. Establish a knowledge network to help develop the region and make efficient use of scant resources through sharing problems, knowledge, and research results.
5. Coordinate the different postgraduate programs in order to avoid unfair competition and promote complementary activities among institutions.
6. Lobby for the establishment of government policies that promote professional training.

I congratulate Dr. Casas for an excellent paper that demonstrates his mastery of the subject and expresses his interest in finding solutions to the problems in this field. The first section of the paper analyzes the population situation as well as production and agricultural training in Latin America, and provides valuable data on these subjects. The second section refers to the Postgraduate College, and the conclusion contributes useful recommendations.

In my opinion, the paper presents issues that can lead to correcting deficiencies.

1. In regard to Eduardo's statement about the greater need for food to satisfy future demands (deficit), there is an apparent contradiction in our countries, since the deficit in some food products increases while the production capacity for other products surpasses domestic demands.

Nonetheless, in both cases there are products with adequate resources for research. Why is it that some research efforts are successful and some are not? Might there be other factors, besides the supply of technological knowledge, which hinder the adoption of research results? The problem should be solved holistically through biophysical research and a parallel analysis of the socioeconomic conditions of production and consumption.

2. A fundamental part of training human resources is in-service training, which has been somewhat forgotten in our countries. I believe this is a good opportunity for cooperation between international centers and national institutions.

3. The demand for postgraduate training in some countries may not be enough to warrant the establishment of a postgraduate program for just one country. This subject should be studied with the view of setting up postgraduate programs among several countries.

4. As Professor Norman Borlaug said, the economic crisis in our countries presents a good opportunity to revive national and subregional postgraduate programs. Training professionals domestically is less costly than training them in foreign countries, although there should always be some foreign training. Given that scientific knowledge is universal, we should be up-to-date on the latest advances outside our borders.

5. A special problem is identifying the real demand for postgraduate training in our nations: this is essential for training the professionals that are really needed.

6. I reiterate what Eduardo stated: it would be best if each country determined the types of research and the scientific fields where specialized training is needed. There have been instances where vast financial resources have been invested in specialized training and the results have not improved work efficiency.

7. Latin America is going through a crisis that has affected its human capital. The brain drain is very serious, and it is time we thought about this problem collectively. I suggest that national research institutes get together with international centers to find solutions to it. Perhaps they could form a work team to prepare the basic diagnosis for each country, and later organize a seminar to study the problem in depth and seek long-term solutions.

Biotechnology: Opportunities for Agricultural Research in Latin America

William M. Roca*

Introduction

Biotechnology has existed for many years; the production of wine, beer, solvents, and drugs through the manipulation of microorganisms and plant products are examples of this science. What sets the emerging technologies, or new biotechnology, apart is the use of knowledge about the interior of cells for directing or manipulating their products (*1*). Recent progress in cellular and molecular biology have application possibilities unthinkable a decade ago, to all production activities: energy, industry, health, and food supply. *In vitro* technologies such as cell and tissue culture, monoclonal antibodies, and recombinant DNA are beginning to be used in agricultural activities. The latest advances are possible because the basic processes of replication, transcription, and translation of genetic information are common to all life forms.

Emerging biotechnologies should be relevant to agriculture in developing countries. Numerous opportunities are directly related to their needs: modifying crop plants to tolerate adverse environments, to be more disease resistant, and fix nitrogen more efficiently; increasing the nutritive value of agricultural products, carrying out quick disease diagnoses, producing useful compounds by bioconversion, etc. On the short or long-term, success will depend on utilization of emerging technologies to reduce time, space, and costs in traditional crop improvement strategies, which necessarily requires a multidisciplinary approach. Breeders and agronomists must be the final recipients of these technologies, and the usefulness of their products must be demonstrated in the field.

The purpose of this document is to discuss the opportunities offered by biotechnology for agricultural research, and its application in national research programs and international agricultural research centers in Latin America. Cooperation among these institutions in research and technology transfer will bring the benefits of biotechnology to the groups that are most in need. The current status of the most important technologies will be briefly analyzed, the situation in Latin America will be discussed, and possible areas of research and cooperation strategies, within and outside the region, will be suggested.

Current Status of Biotechnology

Biotechnologies with the greatest potential in agriculture are: cell and tissue culture, recombinant DNA and gene transfer, monoclonal antibodies, and bioconversion.

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Cell and Tissue Culture

Clonal propagation *in vitro*—Tissue culture is the route which most forms of genetic manipulation should take in the transition from laboratory to field. Therefore, the ability to regenerate plants by means of cell and tissue culture is necessary for the utilization of most biotechnologies.

Plant regeneration can take place by nonadventitious routes, e.g., enhancement of axillary shoots; or through adventitious routes, e.g., differentiation of organs directly from plant parts *in vitro*, or from cell masses or callus induced from plant parts; and by means of somatic cell embryogenesis, which consists of the differentiation of embryo-like forms from individual cells of isolated plant parts or callus.

In 1968, there were approximately 30 species which were propagable *in vitro*, in 1978, there were more than 300, and a 10-fold increase is expected over the next decade (2). Schemes for massive *in vitro* propagation are known. Somatic cell embryogenesis offers tremendous propagation potential, in addition to the possibility of producing "artificial seed" by encapsulating embryos in gels. In spite of the fact that *in vitro* propagation of difficult species (e.g., coniferous trees, mango trees, palm trees, rubber trees, etc.) is being developed, the control of regeneration in economically important plants is still one of the most important constraints for the effective utilization of new biotechnologies. Advances in the metabolic and molecular regulation of cell differentiation should eventually allow the control of plant regeneration *in vitro*.

Disease elimination—Disease-free clones have been recovered from approximately 55 crop species by tissue culture. The technique is valid for all pathogens, but is especially useful for eliminating virus and viroids from vegetatively propagated plants. The most common method is culturing the shoot apical meristem plus one or two leaf primordia. Thermotherapy or chemotherapy is frequently applied to infected plants or to *in vitro* cultures (3). Since all plants regenerated *in vitro* are not necessarily virus-free, the use of virological techniques to demonstrate the absence of viruses is important.

Tissue culture has been used to rehabilitate local cultivars which had lost their vigor and yield (e.g., potato, strawberry, fruit trees, cassava, etc.). The yield of two cassava cultivars doubled and tripled, respectively, as a result of tissue culture from virus-infected plants (3). Yields of the variety "Secundina" increased from 9 to 25 t/ha and remained stable for three years; however, yield of a hybrid decreased after the third year of planting in the same region (Table 1). Interestingly, 30% and 50% yield increases have been obtained with two cassava cultivars, respectively, following *in vitro* propagation of apparently healthy plants (3). These results demonstrate the potential of *in vitro* propagation for the production of basic "seed" in vegetatively propagated crops. Yield increase is often accompanied by changes in plant morphology which favor a more efficient distribution of growth; this has been manifested in cassava by increases in the harvest index.

Germplasm conservation and exchange—Disease-free clones can be used for germplasm exchange by *in vitro* techniques, thereby minimizing the risk of disease and pest dissemination. Furthermore,

germplasm collections can be stored *in vitro*, reducing cost of maintenance in the field and loss of material due to diseases and pests, weather changes, and soil problems. A simple procedure of *in vitro* conservation consists of minimizing the growth rate of cultures by temperature or through modification of the culture medium. Ideally, although still experimental, storage of plant material in liquid nitrogen (-296°C) should provide the maximum stability in the long term.

Wide crossing—The excision and culture of immature embryos on defined culture media have been used to obtain viable plantlets from interspecific and intergeneric crosses which otherwise mightnot succeed. Hybrids from more than 50 crosses have been obtained by using embryo, ovule, and ovary cultures (4). Other techniques such as ovule fertilization *in vitro* and embryo implantation on normal endosperm can also be used to obtain viable F_1 hybrids. Callus induction using immature interspecific hybrid embryos, followed by plant regeneration, can be a rapid way to produce hybrid plants with more stable genomes (5).

Haploidy—The incorporation of haploids into breeding programs is desirable to obtain rapid homozygosity, to incorporate and rapidly fix new genes after sexual recombination or after mutagenesis, to increase selection efficiency, and to minimize retention of deleterious genetic material; in addition, haploidy could pave the way to F_1 hybrid seed production in cross-pollinated and heterozygous species.

The most common method for producing haploids is the culture of anthers containing immature pollen. Plant regeneration, via somatic cell embryogenesis or via organogenesis, depends on genotype, developmental stage of the microspores, culture medium, and anther or bud pretreatments. Callus formation can lead to changes in the chromosome number of regenerated plants. Anther culture has been used to produce haploids of 47 species including rice, oat, barley, wheat, rye, maize, triticale, pea, potato, etc.

Table 1. Yield of cassava (cv. Secundina) in the northern coast of Colombia following elimination of a viral mosaic disease by tissue culture, compared with the hybrid CM 342-170[a]

Clone	Cycle	Fresh roots (t/ha)	Starch (t/ha)	Stem cuttings (No./plant)
Secundina	1st year	25.1 a	7.1 a	10 a
	2nd year	23.0 a	6.8 a	10 a
	3rd year	22.0 a	5.6 a	9 a
	Control[b]	8.9 b	2.1 b	3 b
CM 342-170	1st year	34.8 a	7.9 a	14 b
	2nd year	36.2 a	8.4 a	10 ab
	3rd year	15.1 b	3.1 b	6 b

[a] Adapted from: CIAT Annual Report ,assava Pathology, 1984
[b] Conventional planting material, without tissue culture

Other systems for the production of haploids are: chromosome elimination during culture of interspecific hybrid embryos, e.g., barley with *H. bulbosum*; by parthenogenesis, e.g., in potato following crossing with *S. phureja*; use of genetic markers, e.g., seed color in maize; genetic induction, e.g., ig gene in maize and hap gene in barley (2). In practice, haploids have been incorporated into potato, wheat, *Brassica*, and rice breeding programs. In Latin America, rice breeding for certain ecosystems where only one harvest per year is possible, such as the upland rice areas of the savannas and the Southern Cone countries, is a process which can take 10 years. Homozygous lines, produced by anther culture from F_1 or F_2 hybrid plants, can be evaluated rapidly by the breeders. This would reduce the breeding process by 4 or 5 generations with enormous savings in land, labor, and inputs. Homozygous rice lines, generated through anther culture, with high tolerance to aluminum toxicity, dwarfness, precocity, and insect resistance are under evaluation at CIAT.

A requisite for the use of anther culture in breeding programs is the production of a very high number of lines. Regeneration depends to a great extent on genotype, but frequently F_1 or F_2 hybrids show a higher rate of regeneration than the parents. In the case of rice, the tissues of the anther wall do not take part in callus induction and approximately 50% of the regenerated plants from microspore-derived callus become diploid spontaneously; therefore they are homozygous. One way of increasing callus production is culturing anthers which are floating on liquid medium (6). In this manner, each callus coming from one microspore can be isolated and cultured as a genetically distinct line. Each callus can in turn give rise to phenotypically different plants; this type of variation and the one that can occur in anther culture of pure lines have been called gametoclonal variation (Figure 1).

Somaclonal variation—Somaclonal variation is the increment of genetic variability in plants regenerated by tissue culture. Variation of monogenic and polygenic, as well as qualitative and quantitative characters, has been observed in regenerated plants, e.g., oat, wheat, sugar cane, maize, tomato, potato, rice, alfalfa, and tobacco. The phenotypical variation of somaclones can result from epigenetic or genetic changes. Epigenetic variation can be caused by alterations in gene expression which are not sexually transmitted, but may be amenable to vegetative maintenance. Such alterations can result from amplification or diminishing of gene copy, or from the movement of transposable elements to positions of the genome influencing its expression temporarily (5).

Genetic variation can be caused by changes in the primary structure of the DNA, inversion, deletion, or substitution phenomena in the nuclear or cytoplasmic genetic material; it can also be due to changes in chromosome structure such as inversion and translocation (7). Genetic variants must be in accordance with heredity laws; this analysis must be carried out on the first or second sexual progeny of the regenerated plants.

Fertile somaclones with T toxin resistance have been selected in maize, starting from cytoplasmic sterile and toxin susceptible plants; this change has been associated with the loss of a specific fragment of the mitochondrial DNA; in the same way, somaclones have been selected in wheat and rice for plant height, precocity, size and number of grains, panicle size, etc. (5).

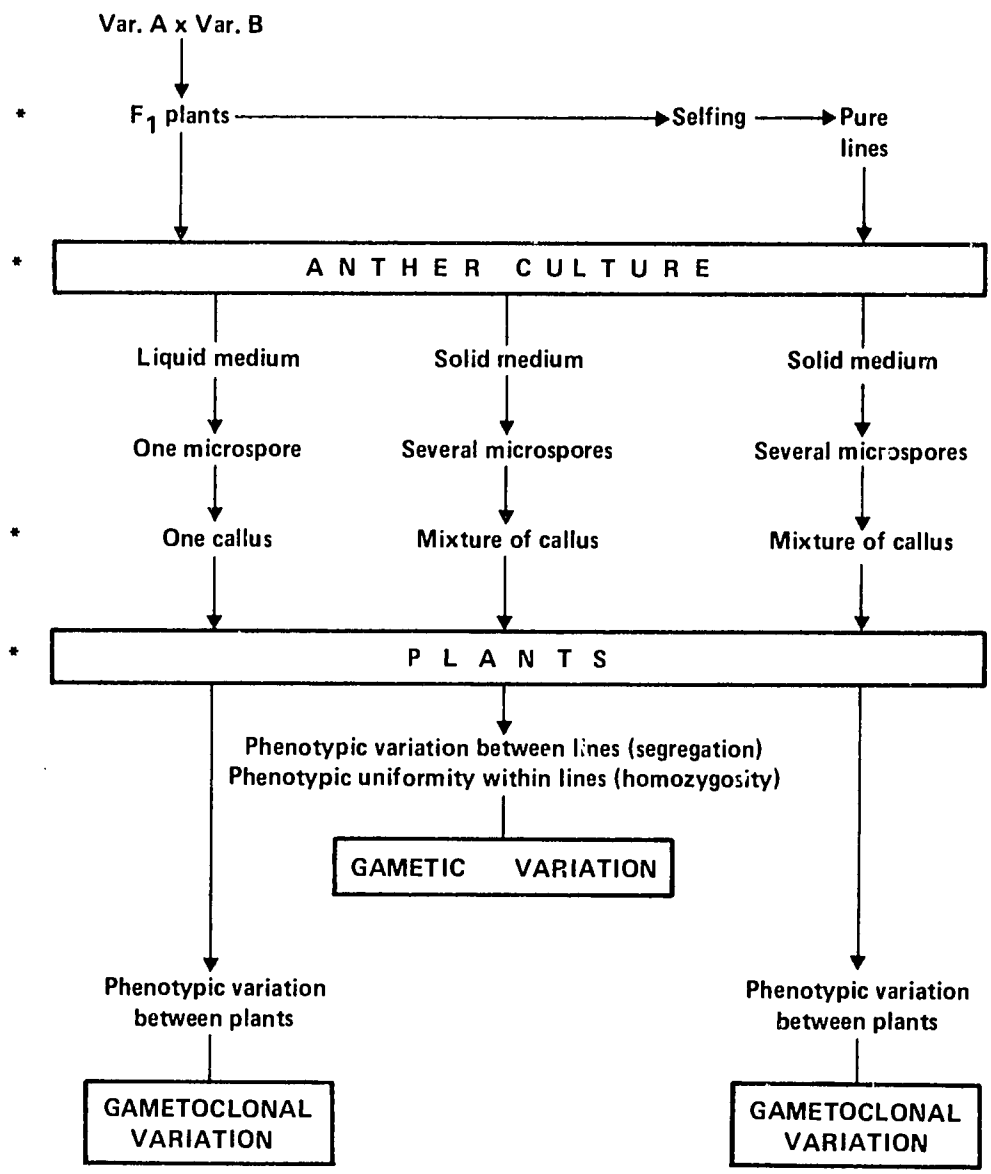

Figure 1. Anther culture as a source of gametic (genetic recombination) and gemetoclonal (genetic recombination +clonal variation) variation (i.e., rice)

* Possible sites for stress (for example, aluminum) to select tolerance *in vitro*

Somaclonal variation has the potential to generate useful variability in adapted cultivars without hybridization; also, somaclonal variation can help to increase the introgression of genes through wide crossing. Due to the current impossibility of controlling somaclonal variation, it is necessary to regenerate a high number of somaclones for use in more conventional selection schemes.

Isolation of mutants—*In vitro* techniques make possible the selection of mutants which can condition useful agricultural changes. Compared to conventional selection, mutant isolation *in vitro* allows the application of very high selection intensities to a very large number of individuals, e.g., one flask with 100 ml of culture medium can contain 5 x 10^4 callus-forming cells, 5 x 10^6 cells in suspension, or one gram of leaf tissue can produce 2-4 x 10^6 protoplasts.

Up to now, 51 cell phenotypes from 20 species have been selected, but only 25 phenotypes from 8 species have been regenerated; genetic analyses of the regenerated plants have been conducted in 9 of these (*8*).

This technique has been used to select resistance to pathotoxins, e.g., potato late blight, maize T toxin, and alternaria in tobacco; resistance to fungi growth, e.g., *Phoma* spores in *Brassica*; tolerance to salinity, e.g., rice and tobacco; tolerance to aluminum toxicity, e.g., tomato; resistance to herbicides, e.g., tobacco and potato; cold resistance, e.g., carrot and tobacco; increasing free amino acids, e.g., lysine and threonine in maize grains due to elimination in enzyme feed-back inhibition; increasing amino acids in vegetative tissues, e.g., tobacco, carrot, and barley; antibiotic resistance, e.g., tobacco and carrot (*7*, *8*).

In vitro mutant selection is limited to traits with simple genetic control and is restricted to species with efficient regeneration from uniform cell or protoplast populations. In principle, the method can be applied when there is correlation between the response of the plant and its cells in culture. Stress application to the plant, followed by culture and regeneration of putatively mutated cells, could be an alternative strategy.

In vitro selection of desired genetic recombinants can be accelerated by applying specific stresses during anther or microspore culture of F_1 hybrids, e.g., genotypes tolerant to aluminum toxicity, iron toxicity, patholoxins, salinity, etc. The application of temperature or other type of stresses at the time of pollen germination and growth could be an interesting technique to select pollen carrying the desired genes. These traits could be rapidly fixed through the culture of anthers of F_1 plants.

Protoplast fusion—This is another mechanism for wide crossing, especially when sexual incompatibility prevents conventional crossing. In addition, it could permit nuclear and cytoplasmic gene recombination and segregation, differing in this respect from sexual crossing.

Apparently there are no barriers to protoplast fusion; nevertheless, the integration of parental genomes in the fused cells can be nil, partial, or complete. It is necessary to have a vigorous selection scheme by which the isolation of fused hybrid cells in sufficient quantities for genetic analysis is possible.

Cytoplasmic fusion, followed by degeneration of one of the parental nuclei, can lead to the formation of cytoplasmic hybrids or cybrids. Elimination of parental nuclei can be performed by micromanipulation with laser rays or radiation. This is a promising mechanism for the transfer of cytoplasmic traits such as herbicide tolerance, resistance to some diseases, male sterility, etc. Cybrid plants with resistance to atrazine and having male cytoplasmic sterility have been obtained from fusions between *Raphanus* nucleus and *Brassica* cytoplasm (*9*).

Difficulty in regenerating plants from hybrid cells or colonies is an important limitation to the use of protoplast fusion. Up to now, only 5 fertile plants have been obtained from 13 regenerated intraspecific somatic hybrids, as well as 15 fertile plants from 28 interspecific ones; most of them belong to the family Solanaceas (*10*). An important somatic hybridization between *S. tuberosum* and *S. brevidens* has recently been achieved (*11*). While these potato species are sexually incompatible, the latter has genes for resistance to economically important viruses.

Recombinant DNA

It is possible to purify, characterize, and even synthesize specific DNA segments through current *in vitro* techniques for DNA manipulation; thus the possibility of directed genetic modification of plants now exists. The process is called genetic engineering.

Genetic engineering, which includes recombinant DNA techniques, involves several interrelated steps: gene characterization; isolation of specific DNA sequences; DNA cloning; transfer of DNA to an appropriate receptor; plant regeneration from transformed receptors (cells, protoplasts, calluses); gene expression in the mature plant and sexual transmission of the trait (*7*).

Gene Characterization

Ideally, the trait chosen for manipulation must be translated into a specific product (an enzyme, for example) and be controlled by one or few genes. Currently, it is not possible to manipulate multigenic traits. Among the important genes that have been isolated and characterized are: the enzyme ribulose -1,5-biphosphate carboxilase oxygenase, important in photosynthesis; the enzyme alcohol dehydrogenase from maize; seed storage proteins of cereals and legumes (phaseoline, lectin, zein, etc.); several genes for N fixation (Nif, and Hup); three nitrogenase genes from *Anabaena*; nodulation genes from *Rhizobium*. The lack of well-characterized genes of economic importance is one of the strongest constraints on genetic engineering; nevertheless, progress in molecular biology is so fast that other gene sequences will gradually become available. In order to characterize genes, it is necessary to identify the portions of the DNA responsible for coding the trait. The insertion of transposable elements into plant genomes can help to isolate and characterize the DNA sequences underlying an altered phenotype (*2*).

Isolation of DNA Sequences

The general procedure for isolating DNA sequences coding for a trait, consists of isolating the messenger RNA (mRNA) from tissue that synthesizes large quantities of the gene product, then building a complementary DNA (cDNA) to the mRNA by means of reverse transcription. Another strategy consists of determining the partial amino acid sequence of the protein produced by the gene in question and translating this sequence into a DNA

sequence. The latter sequence is then utilized to build a cDNA. These steps can be carried out using special machines that save time and costs.

DNA Cloning

Treating nuclear or cytoplasmic genomes with restriction enzymes yields specific DNA fragments of variable size. These fragments can be spliced to bacterial plasmids for storage to form the so-called gene libraries. The cDNA, built as above, can be used as probes to detect and isolate specific DNA sequences from structural genes. For this, DNA fragments of the gene library are separated electrophoretically and immobilized in a matrix to which a radioactive cDNA probe is applied. Complementation of the nucleotide sequences of the probe and the structural gene is visualized by autoradiography.

The cDNA requires amplification which is accomplished by splicing to plasmids before the hybridization step.

Plant DNA cloning can be a routine procedure, provided that genes have been fully characterized.

Gene Transfer

DNA must be introduced in a plant in such a way that genetic information can be expressed; to achieve this, DNA must pass successfully through all the cell's surveillance systems to reach the nucleus. Several transfer strategies exist: direct microinjection to cell or protoplast nuclei, co-culture with haploid or diploid cells or protoplasts, and use of DNA-containing viruses and bacterial plasmids as vectors.

Plasmids Ti and Ri of *Agrobacterium* are the preferred vectors to transfer gene to dicotyledons. The DNA sequence to be transferred is spliced to the T-DNA region of plasmids and, after the plant cells have been infected with bacteria, the T-DNA covalently joins the nuclear DNA. Recently it has been possible to mutate the T-DNA and eliminate its oncogenic effect (*12*).

Selection of Transformed Cells

Since the frequency of transformation is generally low, it is necessary to treat large cell populations and use efficient selection systems. Availability of genetic markers is therefore very important, e.g., identification of opines synthetized by transformed cells (*12*), differential resistance to antibiotics, etc.

Plant Regeneration and Gene Expression

Plant regeneration from transformed cells is of crucial importance for the practical utilization of genetic engineering. It is not enough to demonstrate transformation at the cellular level; the transferred trait must be expressed in the mature plant and in its sexual progeny. Furthermore, gene expression must occur developmentally in the correct plant tissue or organ; for example, expression in roots of genes coding for inhibition of leaf respiration could kill the plant.

Opportunities for Crop Genetic Engineering

Improvement of crop varieties by recombinant DNA techniques is not too far off, at least in the case of traits with simple genetic control. Until now, most work has dealt with model systems (e.g., tobacco and carrot). Gene transfer for antibiotic tolerance using Ti-plasmids as vectors, through tissue infection or co-culture with protoplasts, has resulted in the expression and sexual transmission of the trait (*13*). Also, introduction and expression of genes encoding the bean seed protein phaseoline to tobacco plants was accomplished using the Ti plasmid as the vector.

The following are some of the plant genetic engineering subjects requiring more study and development: identification and characterization of economically important genes; developmental regulation of gene expression; manipulation of weakly linked structural genes or genes with independent segregation; manipulation of traits controlled by nuclear and cytoplasmic genes simultaneously; transfer of polygenic traits; development of gene vectors for monocotyledonous plants; efficient plant regeneration from transformed cells.

A great challenge to genetic engineering is achieving the subtle combination of a large number of genes, each with small effects, into a single genotype, as has been the aim of traditional breeding. The introduction of specific genes to a selected cultivar without disturbing the adapted genetic background of the cultivar might be a useful application of modern techniques.

Among the traits amenable to recombinant DNA manipulation, the storage of seed or tuber proteins is worth considering. Short fragments of DNA, encoding proteins with improved levels of essential amino acids, could be synthesized *in vitro* and linked to *Agrobacterium* plasmids. Following plant or cell infection, regeneration of plants is a necessary step. This is a possibility in the case of bean phaseoline, whose genes have been well characterized and are known to be transmitted as a single Mendelian block (7). Similarly, the manipulation of protein quality and quantity in potato, sweet potato, barley, wheat, and soybean are interesting possibilities, as is the introduction of protein-encoding genes to cassava. In cases where regeneration techniques are not available, other strategies, such as DNA microinjection to germinating pollen grains or developing ovules, could be utilized. Soaking germinating pollen in solution of small DNA fragments before pollination is another interesting transformation technique.

Other traits with potential for manipulation are: tolerance to heavy metals and/or salinity; resistance to herbicides, pathotoxins, and viruses. Manipulating genes responsible for nitrogen fixation is a long-term task because of the complex genetic regulation of the process.

Finally, yield potential is a difficult trait to improve by traditional breeding methods. Biotechnology can offer some strategies for gene transfer from wild species: in a shorter term, hybrid embryo culture and anther culture from F_1 hybrid plants and, in a longer term, gene transfer from distant relatives using recombinant DNA techniques.

Other Uses of Recombinant DNA

It is possible to build a cDNA using a virus RNA as template. The cDNA can be used as molecular probes of high specificity and sensitivity to detect virus or viroid nucleic acids through the formation of RNA-DNA hybrids (*14*). This spot hybridization technique can be used to select germplasm resistant to viruses, or for detection of virus-free plants. Once the virus has been purified, the development of this technique is rather fast. A current limitation is the requirement of a radioactive label for the probe; nevertheless, there is progress in the development of nonradioactive molecular probes.

In a similar manner, DNA probes can be built from DNA fragments encoding specific traits. Such probes can be used to select germplasm with genes that have been introduced by wide crossing (*15*).

Monoclonal Antibodies

Hybridoma cultures, resulting from the fusion of cancerous cells and antibody cells that produce a single type of antibody, have the ability of secreting highly specific antibodies *in vitro* indefinitely (*16*). Monoclonal antibodies can be used to detect pathogens, particularly viruses, when serology is not specific enough, or serum is not available in sufficient quantities. Monoclonal antibodies can also be used for rapid and low-cost disease diagnosis in seed certification programs or quarantine work.

Bioconversion and Production of Useful Metabolites

Total utilization of the plant, and not only fruits or grains, is an interesting possibility. Plant biomass separation in cellulose, hemicellulose, and lignin fractions could provide material for bioconversion. Microbial protein, solvents, and chemicals are possible bioconversion products. Research should be done on lignin utilization in agriculture as well as cellulose fermentation. These technologies have received great attention in some developed countries such as Japan.

Production of specific plant substances using modern biotechnology may be a more interesting possibility for developing countries. Extraction of certain compounds (pigments, alkaloids, antomicrobial substances, drugs, insecticides, etc.) that occur naturally in native tropical species has occupied scientists' attention for many years. It now is possible to culture cell lines that can produce high yields of a given compound on a large scale using bioreactors. Product extraction can be made more efficient through cell immobilization techniques. This alternative can be useful mainly when the species grows in distant places, in small populations, or when field propagation is difficult. In contrast with recombination DNA biotechnologies, plant regeneration is not necessary in this case; genetic modification for producing different chemical structures is a possibility for the future. Nevertheless, one must remember that plant cells, in comparison to microbes, grow more slowly; conservation of specific cellular lines can be difficult, although cryogenic methods may offer solutions in the future. For these reasons, plant cell culture could be used mainly for the biosynthesis of high unit-value products.

Agricultural Biotechnology in Latin America

National Institutes

Table 2 shows the number of national institutes in Latin America where various kinds of biotechnological research of current or potential relevance for agriculture is conducted. This information was drawn from 70 institutes in 11 countries, giving a clear, though not complete, idea of the present situation in Latin America. A Latin American directory of biotechnology is being prepared which will include persons being trained at institutes in developed countries.

Clonal propagation *in vitro*, a technology which has reached practical application, is being used at national agricultural research institutes (INTA in Argentina, INIPA in Peru, etc.) and at higher education institutes (e.g., universities) for crop disease elimination in vegetatively propagated crops and fruit and forest trees. As can be predicted, research in more modern technologies (somaclonal variation, protoplast culture, recombinant DNA), besides basic studies in biochemistry and morphogenesis, is concentrated in the basic research institutes of the region (SENA in Brazil, CENIC in Cuba, etc.) and in higher education institutes. Nevertheless, very useful technologies, such as embryo rescue and haploidy, have not been sufficiently adapted in the national agricultural research institutes.

Table 2. Research in agricultural biotechnology at the national institutes of 11 Latin American countries, August, 1984

Technologies	No. of countries	No. of institutes[a] NARI	IHE	IBR
In vitro clonal propagation	11	21	24	6
Wide crossing (embryo rescue)	2	2	1	1
Haploidy (anther culture)	3	–	3	–
Somaclonal variation and *in vitro* selection	5	1	3	–
Protoplast culture and fusion	4	–	2	3
Recombinant DNA	7	2	2	5
Biosynthesis (cell cultures)	2	–	2	2
Biochemical studies (cell cultures)	5	–	4	6
In vitro morphogenesis	4	–	4	3

[a] NARI: National agricultural research institutes
IHE: Institutes of higher education
IBR: Institutes of basic research

From the above, the following division of labor emerges: the basic research institutes and higher education institutes conduct work with emergent, and thus less developed, technologies; national agricultural research institutes are mostly engaged in technologies which have reached practical application, with the exception of two which conduct recombinant DNA-related research.

Three basis research institutes and one higher education institute can be identified in the field of molecular research, with potential to conduct research in plant recombinant DNA technologies. Collaborative research projects between national agricultural research institutes, basic research institutes, and higher education institutes are lacking; such collaborative projects could help direct the basic studies of the latter toward relevant agricultural problems.

International Agricultural Research Centers

The national agricultural research institutes and the international agricultural research centers make up a system for research in agriculture. They cooperate to achieve increased productivity of basic food crops and cattle production in Latin America. This cooperation should continue in the field of biotechnology.

Table 3 shows the state of development of several biotechnologies at the Latin American international centers: CIAT, CIMMYT, CIP, and CATIE. Technologies with potential to reduce time, space, and costs of specific processes have been developed in conjunction with institutes in developed countries. The objective of the international centers is the integration of the new techniques into current breeding strategies. In this fashion, clonal propagation by tissue culture techniques was the first to be adopted (Table 3). The complete implementation of these techniques has facilitated the flow of germplasm between the international centers and national agricultural research institutes, as well as the development of germplasm banks of vegetatively propagated crops.

Other technologies used at these centers help to achieve interspecific and intergeneric transfer of valuable traits; thanks to anther culture, a final product can be obtained in the laboratory which is similar to the product obtained in the field, but saving time and costs. Advanced molecular technologies are used to increase the efficiency of virus detection. Soon it will be possible to select cell variants in the laboratory that can be extrapolated to plants with new attributes.

The international centers should continue acting as a bridge to transfer available biotechnological advances from institutes in developed countries to tropical agriculture. To accomplish this, the centers have the comparative advantage of a multidisciplinary approach in their research programs, as well as knowledge of the factors that limit progress in their research areas. World germplasm collections at these centers are another important asset.

Institutes in Developed Countries

Most investment in biotechnology is concentrated on human and animal health (interferon, insulin, growth hormone, hemophilia treatment; *in vitro* disease diagnosis, vaccines, etc.) and plant bioprocessing. Including basic research companies (Biogen, Genetech, Genex, etc.) and multinational companies (Monsanto, du Pont, etc.), at least 500 biotechnology companies

operate in developed countries such as the United States of America, Japan, Germany, France, England, and Switzerland. In the United States more than 35 basic research companies are active in agriculture, with an investment of close to 3 billion dollars (*17*).

Basic research for the development of biotechnologies is carried out in basic research institutes and universities. Multinational companies invest in start-up research companies which in turn consider the multinationals as a means of commercializing their products rapidly. Especially noteworthy is the increasing participation of start-up and multinational companies in basic research projects carried out by universities. The former invest in the universities, or scientists from the universities are hired by private

Table 3. Biotechnological research at the international agricultural research centers of Latin America, August, 1984

Technologies	Progress of technologies by crop[a]		
	Beginning	Developing	In use
In vitro clonal propagation	–	Coffee, plantain	Potato, cassava, pastures (gram.)
Wide crossing	Beans	Maize	Wheat
Haploidy	–	–	Rice, potato
Gametoclonal variation	–	Rice	–
Somatic embryogenesis	–	Cassava	--
Somaclonal variation	Cassava	Pastures (legum.), wheat, potato	–
In vitro selection	Rice, potato	–	–
Protoplast culture	–	Potato, cassava	–
Transformation (DNA absorption)	–	Maize	–
Recombinant DNA			
viroid probes	–	–	Potato
protein improvement	Potato	–	–
Cryogenics	–	Cassava	–
Genotypic markers	Beans	Cassava, pastures	Potato

[a] CIAT (cassava, rice, beans, tropical pastures), CIMMYT (maize, wheat); CIP (potato); CATIE (coffee, plantain)

companies. This phenomenon is privatizing biotechnological research in developed countries (*18*).

Cooperation in Biotechnological Research

To develop biotechnological research capability in Latin America, it is necessary first to have adequate access to information on basic aspects and techniques. Traditionally, universities in developed countries have been the main source of scientific training for Latin America; it is desirable that this relationship continue in biotechnology.

In view of the current trend toward privatization of biotechnological research, cooperation between national and international institutes and universities in developed countries should be strengthened.

Figure 2 shows current relationships and proposed new areas of cooperation. It is essential that the national institutes for agricultural research in Latin America prepare themselves to use the most developed biotechnologies, but with few exceptions, this is not the case.

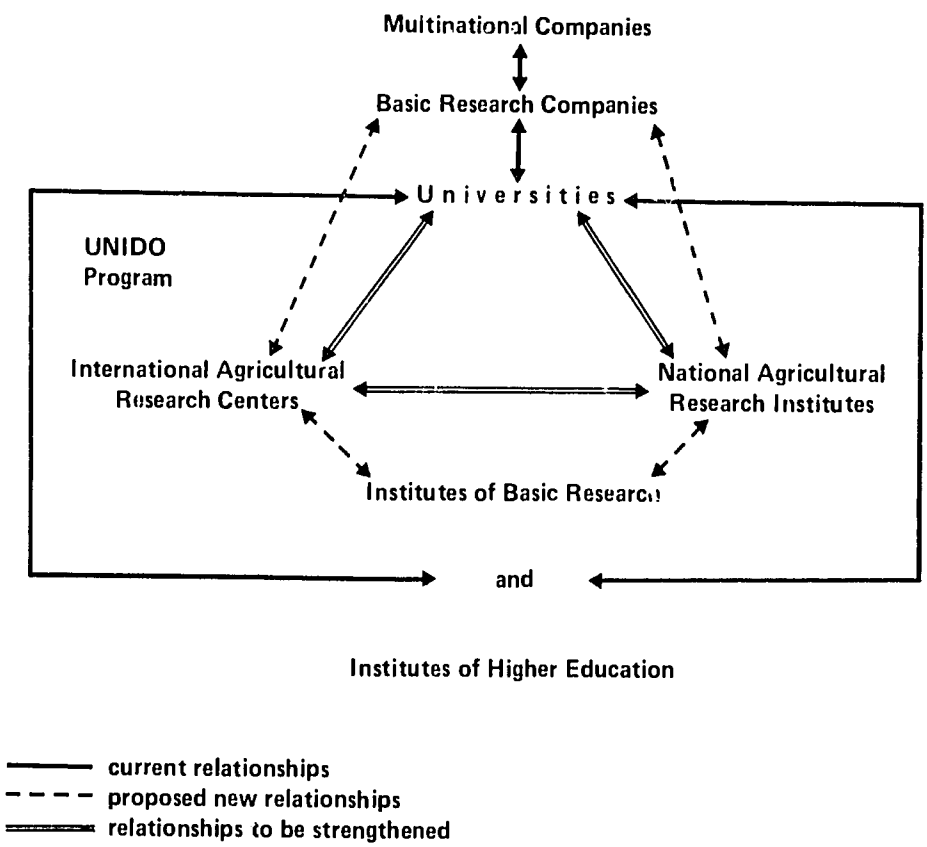

Figure 2. Cooperation in agricultural biotechnology among national research institutes, international agricultural research centers in Latin America, and universities in developed countries; their relationship with biotechnology companies in developed nations

The international centers can select technologies with higher potential for transfer to the national institutes in view of the comparative advantages previously mentioned.

National agricultural research institutes should also establish research links to basic research institutes and higher education institutes with a good level of basic preparation. The establishment of research relations between international centers and national institutes and the basic research companies in developed countries is an alternative. The basic research companies develop technologies which are mostly oriented to highly developed markets; besides, the crops or varieties which are subjects of improvement at those companies generally are not basic to tropical agriculture. For these reasons, it is likely that universities in developed countries will continue to be the main source of biotechnology training for Latin America.

In the case of several tropical crops which have received very little attention in industrialized countries, developing the basic knowledge on genome organization and genetic regulation, which may eventually lead to the manipulation of important traits, is fundamental.

Biotechnology research and development progress rapidly. Besides the well-known journals on cell and tissue culture, molecular biology, molecular and applied genetics, etc., the following are possible sources of critical information on biotechnology:

1. International conferences: International Association for Plant Tissue Culture (every 4 years); International Plant Molecular Biology Association (every 2 years).
2. General news: Nature (monthly) and Science (monthly).
3. Information on activities of institutes, conferences, methodologies, and bibliography: IAPTC Bulletin (quarterly), Plant Molecular Biology Newsletter (every 2 months).
4. Summaries of new discoveries: Agricell Report (monthly), Agricultural Biotechnology News (every 2 months), Genetic Engineering News (8 per year), Mc Graw Hill's Biotechnology Newswatch (every 2 weeks).
5. Research summaries: Molecular Biology Reporter, Biotechnology Research Abstracts (monthly), Bio/Technology, Telegen Reporter (monthly), Telegen Reporter Review, Index and Abstract (annual), Telegenline (data base), Telegen Alert (hot line every 7 days).
6. Technology identification and evaluation: ATAS Bulletin of the Science and Technology Development Center, United Nations (bi-annual).
7. Short training courses in Latin America: Subjects: Selected techniques on tissue culture, General methodologies on tissue culture, Molecular biology and genetic engineering techniques.
   Institutes: International agricultural research centers, ICRO/UNESCO.

   National institutes: Campomar Foundation, Argentina; Pontificia Universidad Católica, Chile; SENA, Brazil; IDEA, Venezuela; National Autonomous University, Mexico.

Another source of collaboration in biotechnology for developing countries will be the UNIDO program which has created the International Center of Genetic Engineering and Biotechnology. This Center is situated in Trieste, Italy and New Delhi, India.

Research areas—Undoubtedly, progress in Latin American agriculture will continue to depend primarily on crop breeding. Therefore, new technologies must be oriented, directly and indirectly, toward this objective. Some opportunities for short, medium and long-term research in biotechnology are:

Short-Term

1. Rehabilitation of local clonal cultivars increase yields and quality of crops.

2. Basic "seed" production in clonal crops for later mass propagation through conventional and unconventional techniques.

3. Massive propagation of new food and industrial species (American tropical palms, fruit trees, forest trees, industrial fruits, etc.)

4. Improved yield potential of crops and increased tolerance to adverse environments (heavy metals, salinity, drought stress, low temperature, etc.) through interspecific or intergeneric crosses, or through *in vitro* manipulations before or after pollination.

Medium-Term

1. Shortening traditional breeding processes through fixation of traits in homozygous lines produced by haploidy (anther culture, parthenogenesis, chromosome elimination, etc.)

2. Rapid disease diagnosis using molecular probes and monoclonal antibodies.

3. Production of varieties with desirable agricultural traits through somaclone selection. This is especially useful for improving adapted varieties without sexual crossing.

4. Selection of variants at the cellular level, with tolerance to salts, aluminum, herbicides, pathotoxins, and other stresses, and increased nutritional value.

Long-Term

1. Increased hybrid vigor in cross-pollinated and heterozygous crops, through rapid homozygosis followed by sexual crossing.

2. Transfer of cytoplasmic male sterility, herbicide resistance, and disease tolerance through protoplast fusion and organell transfer.

3. Genetic engineering transformation of crops. Introduction of DNA sequences encoding traits of economic importance: tolerance to adverse environments; improvement of grain, tuber, and root protein quality; increase of yield potential and total biomass yield of crops; increase of photosynthetic efficiency and nitrogen fixation.

This classification is relative to current and future (next decade) development of the national agricultural research institutes in the region.

Conclusion

Biotechnology now offers a wide range of new technologies that may increase the efficiency of specific processes in crop improvement. Choice of the appropriate technologies is essential to success in applying them. This requires that national research programs give priority to training personnel in emerging technologies; therefore, access to biotechnical information is of critical importance. Cooperation among national agricultural research institutes, international research centers, and universities and institutes in developed countries is indispensable to develop biotechnological capabilities in Latin America.

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Comment

Ezequiel Espinoza*

There are different levels of biotechnological research applied to agriculture, and in my opinion, some of the problems that should be discussed are:

(a) Which institutions should work on the different phases of biotechnological research?

(b) How should such research be financed?

(c) What would be the roles of international centers and national agricultural research institutes?

I agree that basic research could be conducted at the universities, basic research institutes, and multinational companies, since they have the best facilities and human resources. National research institutes could do development research. In my opinion, international centers have the capacity to participate in both aspects, which would make them the link between the universities, basic research institutes, and multinational companies, on the one hand, and the national agricultural research institutes, on the other. The centers would have the advantage of selecting new technologies with the best potential for later transferral to national programs.

According to available information, some universities and basic research institutes in Latin America are beginning to explore the era of biotechnology. This information could be interpreted to mean that the institutes are doing development research in biotechnology, but the national research institutes, with a few exceptions, have only done clonal propagation *in vitro*. International agricultural research centers in Latin America that have mastered micropropagation techniques in their designated crops have started development research and are preparing to begin genetic engineering. This may be taken to mean that the centers are working on development aspects and are carrying on basic research in biotechnology.

Without a doubt, short, medium, and long-term research is costly, and its results are not always positive; biotechnology research costs are even higher. In many cases, national research institutions do not carry out research and development activities because they lack political support; this means low, poorly balanced budgets and a lack of well-trained professionals. The State cannot cover the costs of all levels of research; for this reason, it has been suggested that private companies share the burden. Sources of financing could be divided according to the rate of return, the time lapse between research initiation and application, and the impact of research on yields and farmers' profits. A good portion of the funds could be supplied by donations, contracts, royalties and other ways of cooperation by private companies, foundations, farmer associations, and international organizations with funds for development.

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National research institutes should solve the practical problems of food production and also do basic and development research; therefore, the institutes' participation in these two aspects should be adequately balanced, priorities should be determined in each country, and action should be taken according to present needs, possibilities, and limitations.

I agree that international cooperation in biotechnological research is essential for reaching the established objectives. There should be different types of cooperation, such as academic training, scientific documentation, international conferences to promote scientific information, donation of equipment and materials, and joint projects. Of these, perhaps the most useful and original aspect is communicating the latest advances in biotechnology to technicians at the various research institutions. This can be achieved through easy and quick access to up-to-date documentation, references, conferences, and other information.

I think that biotechnological research in agriculture should be aimed at solving practical problems. Some established objectives, such as the erradication of diseases, germplasm conservation, shortening the time it takes to select a desired trait, broadening genetic diversity in crops, tolerance to adverse conditions, and increasing the nutritious content of some farm products qualify as practical problems.

The fact that basic seed that is free of virus diseases has been produced through *in vitro* propagation, and that through the same technique germplasm can be transported from one country to another without the risk of spreading disease is very important in vegetatively propagated crops such as cassava and potato.

In Central American countries (whose situation I am more familiar with), sustained production of basic grains is essential for satisfying the people's food demand. Genetic improvement of rice through anther culture is undoubtedly a valuable complement to traditional rice-breeding methods. Research in crops such as beans would greatly benefit Central American countries, where production is much diminished by virus diseases; efforts in breeding wheat varieties for tropical environments would lead to regional production of a grain that has high consumption levels in Central America.

In my opinion, the twelve concrete propositions regarding biotechnological research opportunities reflect an escalating degree of difficulties and costs, starting with development research and ending with basic research.

In conclusion, I wish to point out that:

1. Biotechnology will have great impact on agricultural development, and our countries should take advantage of it.

2. The job of adapting basic research and transferring it to national agricultural research institutes should be carried out by international research centers, given that universities and basic research institutes in Latin America do not have the technical or financial capabilities to do so.

3. National and transnational companies should take part in financing basic and development research (including biotechnological research).

4. International cooperation should be of various types: among them, prompt dissemination of knowledge generated by biotechnological research.

Barbara McClintock*

Dr. Roca is to be congratulated on the extent of his review of modern techniques for obtaining desired changes and for modifying phenotypic expressions and genotypic constitutions. His suggestions for improving the teaching and application of these techniques are welcome. Personally, I was much interested in his discussion of conditions that induce change in phenotypic expressions. My researches with maize were focused on this topic over many years. The early maize studies and those now being conducted with maize and with many other plant and animal organisms have produced surprising results. These are highly significant in that they are responsible for revolutionary changes in our concepts of the organization and operation of genetic materials. Essentially, this reflects the fall-out from recent advances in molecular techniques. As a consequence, we now have detailed knowledge of the constitution of genetic materials. Also we are learning much about how these operate, either as expressions of normal regulatory systems or after changes in these systems when the genome is subjected to stress. Some of the techniques now used to modify genomes depend on mechanisms already present in the genome, which, in response to stress, modify the genome in a programmed manner. These modifications are responsible for many of the observed changes in phenotypic expression.

It is becoming increasingly clear that cells are highly sensitive to various perturbations originating either from exterior sources or from within the cell itself. It has been learned that responses to perturbations may initiate changes in composition and organization of particular components of the hereditary materials. Some of the results of applications of techniques discussed by Dr. Roca reflect just such responses. With plant materials, these modifications are readily detected in cells that have been subjected to new situations, such as removing cells from their normal environment and placing them in a tissue culture medium. Often the cells are stressed by this change, and genomic alterations may result. Again, such alterations may occur whenever a cell senses a block in the functioning of a system that is required to provide a needed product, or that demands a precise sequence of cellular events. Forty years ago, just such a block occurred in the course of an experiment with maize that I had designed and conducted with the expectation that all would proceed in a simple and direct manner. The outcome of this experiment was anything but simple. Rather, the results were considered bizarre. The experiment was undertaken before DNA was recognized as the basic genetic material, and much before anything was known about the mechanisms of gene regulation. It turned out, however, that the instigator of the bizarre genetic expressions was associated with the entrance into a telophase nucleus of a chromosome with a newly-broken end (the break having occurred as the result of pull on the chromosome arm during chromatid separation at the preceding anaphase).

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It was not anticipated that this situation would shock the cell and thereby initiate various types of chromosomal reorganizations. However, these occurred and they included activations of previously undetected chromosome elements with capabilities for transposing from one location in the chromosome complement to another. Following activation, an element could enter a gene locus and take over control of its expression. It was determined that these elements could give rise to many new alleles of a gene that would thereafter behave as stable alleles of the gene.

It is now known that responses of genomes to challenge can initiate many types of genetic change. The induction of specific chromosome elements that are potentially capable of transposing is only one of these. Some of the techniques discussed by Dr. Roca are known to induce distinctive types of change. In any one instance, the type or types of change may be determined initially more by experience than by projection. Once the nature of an event is recognized, the components involved in the inductions may be determined. The particular system may be used subsequently with confidence of success.

A number of studies have revealed an elaborate sequence of events that mitigates or eliminates potential damage to the genome. It reflects responses to traumatic experiences. In many instances, the genome is programmed to respond effectively. An example is the elaborate sequence of cellular events known to occur in all or nearly all organisms whenever the temperature is elevated beyond a certain degree. When effective, there is no damage to the genome. In some other instances, response to trauma may induce slight alterations of the genome. In still other instances, the response to trauma may induce many changes in the genome, although the types and the time of their occurrences are not precisely controlled. Nevertheless, experience shows that particular traumas, such as tissue culture initiations, the sensing of poisons, and especially the trauma initiated by species crosses, instigate their own specific types of genome restructuring.

So much has been learned in recent years about the plasticity of the genome that it is difficult to recall how restrictive our earlier concepts of the nature and operation of genetic materials were. At present, conceptual formulations are subject to continuing revision. These changing concepts are affecting all branches of biology. This is especially so with regard to interpretations of evolutionary mechanisms. Truly, we are in the midst of a genetic revolution that is extending to all biological disciplines. For a person who has been associated with genetics since 1921, this new burst of conceptual restructurings is one of the most provocative and stimulating that has been witnessed.

What have modern techniques revealed that has caused such a revolution in biology? There is so much that it cannot be summarized in a few statements. A selected example may illustrate one aspect of this. It is now recognized that the "lowly bacteria" may no longer be considered lowly.

Bacteria are highly sophisticated organisms. Consider, for instance, the recently discovered, technically complicated "rotary motor" that rotates the bacterial flagella and thereby moves a bacterium in a selected direction. Changes in this direction also involve the motor. A change occurs in response to decisions associated with a sensing mechanism. A bacterium can sense alterations in its internal or external environments. The bacterium interprets each alteration and then initiates a sequence of highly complex but clearly programmed operations. All organisms operate with sensing mechanisms and it is to them that we must turn for an understanding of the extraordinary genomic changes that do occur as a consequence of the sensing of some abnormal or dangerous situation.

Just now the future of biology looks bright and promising.

Summary

Victor Palma*

The workshop on strengthening agricultural research in Latin America and the Caribbean, which took place on September 10-12, 1984, at CIMMYT headquarters, was sponsored by IDB and CIMMYT. In the course of the workshop, six papers were presented and discussed that analyzed trends in production, consumption, and trade of the main agricultural products of the region, investments to strengthen agricultural research, agricultural research characteristics, on-farm research, and development of research and human resources in biotechnology. The workshop provided the opportunity for dialogue between directors of national and international agricultural research organisms and IDB officials on strengthening the mechanisms for cooperation. In addition to the presentation of papers, the workshop included comments by specially selected scientists, as well as the comments and opinions of participants during discussions in seven work groups. From this material, I have arrived at the following conclusions and recommendations.

Conclusions

There are rapid changes in food consumption patterns in the region caused by the high rate of rural-urban migration, the urbanization process, the rise in income, and the present structure of relative prices. These changes tend to increase the demand for animal proteins (beef, poultry, eggs, and dairy products) and, to a lesser degree, for vegetables, fruits, vegetable oils, and wheat. There is also a diminishing demand for roots and tubers, as well as for dry legumes (cassava, potatoes, beans, and maize for human consumption).

- As a result of the changes in demand, there are corresponding modifications in the production and supply components. For example, there is a marked increase in the use of grain as animal feed.

- The large population masses that have migrated to urban areas have maintained their habits of consuming nonprocessed food products (rice, beans, cassava, plantains, potatoes, etc.); real prices of these staples tend to increase while their production growth tends to diminish.

- The economic, political, and scientific circumstances of the 1980s indicate the need for a better balance between basic and applied research, and for high-level professionals in national institutes to conduct basic research, for instance, in biotechnology.

- National institutions face the dilemma of having to follow short-term agricultural and economic policies that are directly opposed to research which, of its own essence, is a long-term process.

- National institutions lack financial stability, personnel, and facilities; this keeps them from carrying out their basic function of solving problems related to the production process.

- There are signs of greater investment opportunities in agricultural research in Latin America; among them: a) the social returns of research are high, and the domestic rate of return in Latin America and the Caribbean is in the range of 30 to 90%, and b) industrialized nations invest more

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than 2% of their farm GNP in agricultural research, while the average investment in Latin American countries is only 0.6%.

- Once again, there is proof that deficient working conditions, low salaries, and lack of adequate incentives drastically reduce the highly specialized researcher's stay at research institutions.

- As a result of the above, many national institutions can only hope to retain less-qualified researchers.

- It is a fact that many research programs in more developed countries and in private companies use biotechniques to generate technologies that are applicable to agriculture and agribusiness. This not only creates opportunities for on-going research programs, but also points up the need to keep researchers and institutions informed of new biotechnological advances. Many national institutions have not yet developed the scientific capability to assimilate information and new discoveries used in solving specific problems.

- The private sector's growing participation in biotechnological research in industrialized nations will probably keep national research institutions from having access to new techniques.

- International centers will play a basic role in linking biotechnological research to national institutions.

- Discussions held here in support of cooperation among international centers, national institutions, and IDB reached the conclusion that the greatest effort should be directed toward strengthening national agricultural research institutes.

- Training in on-farm research and new fields such as biotechnology was deemed fundamental. First priority was given to training in research management and administration, and especially to establishing priorities and assessing projects.

Recommendations

- Technology development must be strengthened to raise production and increase the supply of animal products and other foodstuffs with rapidly growing demands (vegetables, fruits, vegetable oils) without neglecting research on other products for human consumption (beans, cassava, potatoes, and dry legumes) that benefits poor consumers and small farmers.

- Research that generates storage and food processing technologies should be promoted.

- Technologies should be generated that help small subsistence farmers to become commercial farmers.

- Funds to conduct research on products with export potential should be increased.

  More funds should be allotted to developing mechanical technologies that are adequate for each country, given that rural-urban migration has greatly reduced the supply of farm hand labor.

- Mechanisms must be created for: a) strengthening the bonds between national agricultural and economic policies and policies on agricultural technologies; b) increasing cooperation with other components of the national research system, such as universities, foundations, private companies, etc.; c) increasing the capacity for solving production problems through on-farm research,

farmer participation in planning and closer cooperation with technology transfer services, and d) achieving enough autonomy and flexibility in national institutions so that they can obtain sufficient financial, material, and human resources to carry out their responsibilities.

- Bilateral relations with organizations such as ISNAR, FAO, IICA, and IADS for diagnosing research problems must be strengthened, and product consultation with international centers must be broadened.

- Long-term complementary financing by multilateral and bilateral institutions such as IDB, the World Bank, and AID must be more flexible.

- The establishment of regional research institutions (e.g., CATIE, CARDI, and UWI), research networks for different products, and cooperative programs between national institutes and international centers should be promoted.

- Cooperative activities through institutions, such as IFARDLAC and IICA in the areas of data bases, management training, and administration of agricultural research institutions, must be supported.

- More horizontal cooperation in agricultural research among countries of the region should be achieved in order to attract more investment by national organizations that promote technical and financial cooperation.

- Research must have a multidisciplinary approach in order to generate technologies that are adequate to farmers' socioeconomic and agroecological circumstances.

- Training and specialization of researchers at various levels should be promoted, and specialized units for training human resources must be established according to each country's needs.

- Support should be given to national institutions that offer advanced training and conduct technical programs which may benefit other Latin American countries.

- Training opportunities at national and international agricultural research centers should be broadened and arrangements made for writing theses and dissertations.

- Scientific and technical links between the universities that conduct basic biotechnological research, the international centers, and the national institutes should be broadened and strengthened. Priority should be given to training scientific personnel to assimilate and adapt new discoveries and technologies.

- Scientists at national institutes should be given access to the continuous scientific advances on which biotechnology depends.

- Biotechnologies should be cautiously and selectively integrated into programs (with the multidisciplinary consensus of the institutes) to reduce the cost of specific activities.

- National research authorities should be consulted so that they may participate in determining the priorities of international centers. Also, authorities should play a significant role in reviewing research conducted by international centers of the CGIAR system.

- The international centers should be brought closer to national institutes through the official agricultural institution in each country.

- Continuous communication among the directors of national institutions should be promoted so that Latin America and Caribbean countries will present a united front at CGIAR meetings, thereby ensuring more effective representation of the region.

- Lobbying should be started for action to bring out the importance of agricultural research in national economic development.

The last recommendations are specifically for IDB:

- IDB should consider that the training costs for each country are included in national contributions, and that they come up to at least 60% of total project cost.

- IDB should give support to regional cooperative programs and to national programs that have comparative advantages in well-defined areas of research so that they, in turn, will aid other national programs.

Message

Antonio Ortiz Mena*

It is an honor and an opportunity for the Inter-American Development Bank to join in the efforts of such a distinguished group of agricultural scientists to establish an open dialogue on a subject that is so relevant to the development of the region: the strengthening of agricultural research.

Latin America is experiencing a period of unparalleled economic and financial crisis and its effects on the employment, health, and nutrition levels of large population masses are becoming less and less bearable. It is therefore urgent to find the means of invigorating regional production systems; the development of the agricultural sector is one of the most solid and feasible alternatives for promoting economic recovery. Adequate handling of our agricultural policies is also an important element for solving the social problems of both rural and urban populations.

Over the last few decades, the agricultural sector has made important contributions to the development of Latin American economies. On the average, agriculture contributes more than 10% of the gross national product. The rate of food production has risen for the region as a whole over the last 20 years, and it is basically self-sufficient in agricultural production. In addition, agriculture is, and will continue to be, a very important source of the foreign exchange necessary for the industrialization process of our countries.

There is no doubt that the performance of the agricultural sector has been a determining as well as a conditioning factor for economic growth. The changes in structure that have taken place in our economies and societies over the last decades, plus the need to overcome the present economic crisis, demand an even greater contribution by the sector than it has made in the past; this will help Latin America to achieve the accelerated pace of development it requires to fulfill its legitimate aspirations. To illustrate this point, it would be sufficient to point out that in the year 2000—that is, in just 16 years—Latin America will have a population of approximately 600 million. Even more importantly, nearly 420 million inhabitants will then live in urban centers where the problem of food supply is already enormous.

I do not believe this is an appropriate occasion for a detailed analysis of the factors that affect trends in population migration, a subject which has been adequately discussed in seminars over the past few weeks. The demographic phenomenon has been clearly identified and, as a result, we should promptly and effectively present solutions that are not only valid, but also feasible within the serious constraints that the international and regional situations impose on our countries' capacity for action.

In this sense, I wish to point out that the increase in agricultural production required as a result of the demographic phenomenon can be achieved either through yield increases or the expansion of cultivated land. In the past, strategies

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for regional agricultural development have been fundamentally based on the latter factor, that is, expansion of cultivated land. But although many countries still have an ample margin within which to continue this expansion, we cannot forget that in the short term, the required infrastructure as well as the high costs of the necessary productive capital make it imperative to concentrate on increasing farm yields more than on continuing land expansion.

Increasing the productivity of land already under cultivation requires a lower capital/product ratio, less investment per ton harvested, and a more effective use of scant financial resources. The emphasis on increasing the productivity of cultivated land as opposed to land expansion—which is perceived as the nucleus of present agricultural strategy in most Latin American countries—is in keeping with the limitations of the present situation.

The challenges that Latin American agriculture is facing therefore demand implementing measures whose efficacy and viability depend basically on the technological advances that can be initiated at all levels of the agricultural productive process.

Developing technology is perhaps the most expedient way for our countries to achieve the same levels of progress as industrialized nations. Research and technological advances thus become conditions *sine qua non* for designing strategies for fast-paced development that will surpass the traditional rhythm of economic growth. Merely reaching a growth pace similar to that of industrialized nations today would, in the best of cases, maintain the same distance between developing and advanced nations. We therefore need to generate our own innovative agricultural technologies to satisfy our demands without delay and make the most of our resources and means.

In these fields, Latin America has made important contributions to research development which have benefited the region and other areas as well. Numerous Latin American specialists have received high international honors for their work; however, the work would be of no value if it were not made widely known nor used efficiently.

Training human resources is a vital factor for success in the process of creating and adapting new technologies In rural populations of developing countries (particularly where the farmer has maintained his traditional practices), short-term changes are not easily brought about. In fact, many middle-range farmers who have received successful financial returns from crop production are not enthusiastic about accepting radical modifications of their proven cultural practices.

At the same time, recent fluctuations in the prices of basic staples make many farmers skeptical of changing to more productive methods. In view of this, one must remember that the process of creating and renovating technology should not only cover the farm cycle from planting to harvest, but must also include the processes leading to the final utilization of the product.

If the price of sugar or soybeans is very low today, that is no reason to stop trying to improve their cultivation methods. It merely indicates the need for finding new uses for important raw materials in which Latin America has undeniable comparative advantages.

Another aspect that should be included in desirable technological changes that can be brought about through research results is better use of natural resources. For example, the correct use of soil according to its natural qualities could greatly increase farmers' income in arid or low-fertility areas through the planting of tree or plant species that are adequate to such soil conditions. This

would be far more logical than planting traditional crops with high irrigation and fertilizer costs; without these inputs, poor yields are achieved at the expense of the irreplaceable loss of soil quality. Although it is not easy to introduce radical changes in marginal farmlands, where the population just barely survives on its present labor, these changes are necessary and they require the intense determination and participation of the government and communities involved in order to bring about changes that will produce short-term benefits.

The aspects I am referring to indicate that scientific and technological research in the agricultural sector requires priority allocations of financial resources, as well as continuity in efforts. Variations and interruptions of the process may mean the practically irreplaceable loss of long years of work. Hence government constraints on fiscal expenditures for agricultural research must be made with great care; in case of inevitable reductions, it is imperative to keep the most valuable assets, that is, human resources, and maintain those programs whose continual progress must be ensured in order to avoid total loss of research efforts.

For these reasons, the Inter-American Development Bank has supported and will continue to support research systems in the region, as well as their three basically interrelated levels: national agricultural research organizations, regional headquarters, and international centers. The Bank's main emphasis is supporting the strengthening of national institutions, given the fundamental role they play in supplying technology for agricultural products. We are convinced that, in coming years public sector expenditure and investment in agricultural research will have to be proportional to the relative importance of the agricultural sector in the economy as a whole. Funds destined to agricultural research in Latin America (on a per capita basis, or when compared to the gross national product, national budget, or gross national farm product) make evident the inadequate support national governments give to research in comparison with the relative amount spent on research by industrialized nations.

For this reason, support given by the Bank to its member nations for research should be matched by the vigorous efforts of national governments and should contribute to avoiding the deterioration of national research systems.

Another dimension of the Bank's activity is the collective efforts of the countries themselves. Cooperative networks in regional research have achieved support among nations that have common geographical characteristics. Thanks to their organization, the networks are an effective means of making the most of scant human and financial resources. Though they are not national program institutes, regional networks facilitate the sharing of information and materials, and they also reduce the problems of countries with limited research capacities. This type of network operates in the Southern Cone and the Andean Zone, and the establishment of other networks, such as the Regional Water Use and Management Network and the Caribbean Research Network, is under consideration. It is the intention of the Inter-American Development Bank to go on supporting regional network activities to which the countries have accorded high priority.

As for international research efforts, it must be remembered that since 1971, IDB has given constant support to the three centers located in Latin America: CIMMYT, CIAT, and CIP. These centers, as well as ten others that make up the international research agricultural system, offer very valuable aid to developing countries through

technology, training, and assessment related to germplasm. Since these centers focus on specific research problems, they are able to obtain significant economies of scale and ensure excellent use of human as well as physical resources. Their organization also guarantees the stability they require to conduct research activities.

It is clear that these centers will have to continue operating in the region for a very long time. They are especially important for smaller countries which, because of their size, cannot carry on the tasks that are inherent to agricultural research. International centers should in the future be willing to adjust their fields of activity as national programs acquire a greater degree of self-sufficiency.

It is important to point out that, besides the level of research conducted, the most relevant factor of an organization dedicated to this type of work is its scientific staff. It is therefore urgent to strengthen the human capital of research institutions in the region, since agricultural science and technology are becoming increasingly complex. Highly skilled specialists will be necessary for the most significant research aspects in plant genetics, plant and animal protection, soils and soil microbiology, as well as other important areas that are fundamental to countries of the region. We must therefore improve the capacity of regional organizations in order to train the scientists, research directors, and extension agents who will form the nucleus of our agricultural technology institutions. Additional mechanisms for communication between our scientists and scientists of other countries must be identified as well.

The directors of national agricultural research centers, represented by this workshop's distinguished participants, play an important role as leaders of agricultural development in our region. They individually and jointly assessed our countries' future needs, and also expressed opinions and gave advice which national authorities will surely take into account in formulating policies and strategies destined to strengthen the agricultural sector. For the Inter-American Development Bank, the results of these deliberations are an invaluable guide in determining the support that it will continue to give this important activity.

Ladies and gentlemen: I am honored to accept the recognition given here today by national and regional research institutions and international centers to the Inter-American Development Bank. IDB, as a service institution to Latin American countries, takes this to be an acknowledgement of the merit and value of the international cooperative efforts in agricultural research to which all participants of this meeting are committed. I wish to express our deepest gratitude to all of you.

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