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Mexico
Agricultural Technology Sector Review

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CURRENCY EQUIVALENTS

Currency Unit	=	Mexican Peso (Mex$)
US$1	=	Mex$3,095
Mex$1 million	=	US$323

(June 1992)

FISCAL YEAR

January 1 - December 31

WEIGHTS AND MEASURES

1 meter (m)	=	3.28 feet (ft)
1 kilometer (km)	=	0.62 mile (mi)
1 hectare (ha)	=	10,000 m^2 = 2.47 acres
1 square kilometer (km^2)	=	0.38 square miles (mi^2) = 100 ha
1 metric ton (m ton)	=	2,205 pounds

ABBREVIATIONS AND ACRONYMS

AALPESS	Local Agriculture Association of Specialized Producers of Seeds for Planting (Asociación Agrícola Local de Productores Especializados en Semillas para Siembra)
AI	Artificial Insemination
AMSAC	The Mexican Seed Trade Association
AZUCAR	National Sugar Company
BANRURAL	National Bank for Agricultural Credit (Banco Nacional de Crédito Rural, S.N.C.)
BCMV	Bean Common Mosaic Virus
BGMV	Bean Golden Mosaic Virus
CAADES	Confederation of Agriculture Associations of Sinaloa (Confederación de Asociaciones Agrícolas de Sinaloa)
CANIFARMA	National Chamber of the Pharmaceutical Industry (Cámara Nacional de la Industria Farmacéutica)
CCVP	Plant Varieties Qualification Committee (Comité Calificador de Variedades y Plantas)
CEICADES	Center for Teaching and Research in Agricultural Sciences and Rural Development (Centro de Enseñanza e Investigación en Ciencias Agrícolas y Desarrollo Rural)
CENID	National Disciplinary Research Center (Centro Nacional de Investigación Disciplinaria)
CETROCAF	Tropical Agricultural and Forestry Training Center (Centro Tropical de Capacitación Agropecuaria y Forestal)
CGIAR	Consultative Group on International Agricultural Research
CIANA	Center for Research in Foods and Animal Nutrition (Centro de Investigación de Agricultura Tropical)
CIAT	International Center for Tropical Agriculture (Centro Internacional de Agricultura Tropical)
CIFAP	Center for Crop, Livestock, and Forestry Research (Centro de Investigación Forestal y Agropecuaria)
CIMEVET	Center for Research in Veterinary Medicine (Centro de Investigaciones en Medicina Veterinaria)
CIMMYT	International Maize and Wheat Improvement Center (Centro Internacional de Mejoramiento de Maíz y Trigo)
CINVESTAV	Center for Research and Advanced Studies (Centro de Investigación y de Estudios Avanzados)

CIP	**International Potato Center (Centro Internacional de la Papa)**
CNA	**National Water Commission (Comisión Nacional del Agua)**
CNIA	**National Sugar Industry Commission (Comisión Nacional de la Industria Azucarera)**
CNM	**National Maize Commission (Comisión Nacional de Maíz)**
CNPH	**National Organization of Vegetable Producers (Confederación Nacional de Productores de Hortalizas)**
CONACYT	**National Council of Science and Technology (Consejo Nacional de Ciencia y Tecnología)**
CONADECA	**National Cocoa Development Council (Comisión Nacional de Cacao)**
CONAFRUT	**National Commission for Fruit Crops (Comisión Nacional de Fruticultura)**
CONASUPO	**National Commission for Distribution of Basic Foods (Compañía Nacional de Subsistencias Populares)**
CPCh	**Postgraduate College of Chapingo (Colegio de Postgraduados de Chapingo)**
CPIAES	**Permanent Commission for Agricultural Research in Sinaloa (Comisión Permanente de Investigación Agrícola del Estado de Sinaloa)**
DDR	**Rural Development District (Distrito de Desarrollo Rural)**
FICART	**Trust Fund for Rainfed and Irrigated Areas (Fideicomiso para Crédito en Areas de Riego y de Temporal)**
FIRA	**Trust Fund for Agriculture (Bank of Mexico) (Fideicomisos Instituidos en Relacion con la Agricultura)**
FMD	**Foot and Mouth Disease**
FSR	**Farming Systems Research**
GDP	**Gross Domestic Product**
IARC	**International Agricultural Research Center**
IBPGR	**International Board for Plant Genetic Resources**
ICA	**International Coffee Agreement**
ICARDA	**International Center for Agricultural Research in Dryland Areas**
ICRISAT	**International Crops Research Institute for the Semiarid Tropics**

IIA	Institute of Agricultural Research (Instituto de Investigación Agrícola)
IMPA	Mexican Sugar Cane Production Institute (Insituto para el Mejoramiento de la Produccion de Azucar)
IMTA	Mexican Institute of Water Technology (Instituto Mexicano de Tecnología del Agua)
INEGI	National Institute for Statistics, Geography, and Information (Instituto Nacional de Estadísticas, Geografía e Informática)
INIA	National Institute for Agricultural Research (Instituto Nacional de Investigaciones Agrícolas
INIF	National Institute for Forestry Research (Instituto Nacional de Investigaciones Forestales)
INIFAP	National Institute for Forestry, Agriculture and Livestock Research (Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias)
INIP	National Institute for Livestock Research (Instituto Nacional de Investigaciones Pecuarias)
INMECAFE	Mexican Coffee Institute (Instituto Mexicano del Cafe)
INTSORMIL	International Sorghum and Millet Project
IRRI	International Rice Research Institute
NPCs	National Protection Coefficients
OEE	Office of Special Studies (Oficina de Estudios Especiales)
OPV	Open Pollinated Variety
PIDER	Investment Program for Rural Development (Programa de Inversión para el Desarrollo Rural)
PLANAT	National Plan for Support to Rainfed Agriculture (Plan Nacional de Apoyo a la Agricultura de Temporal)
PROCATI	Program for Training, Technical Assistance, and Research (Programa de Capacitación, Asistencia Técnica e Investigación)
PRODERITH	Program for Integrated Rural Development of the Humid Tropics (Programa de Desarrollo Rural Integral para el Trópico Húmedo)
PRONAFAT	National High Technology Bean Program (Programa Nacional de Frijol de Alta Tecnología)
PRONAMAT	National High Technology Maize Program (Programa Nacional de Maíz de Alta Tecnología)
PRONASE	National Seed Company (Productora Nacional de Semillas)

(Productora Nacional de Semillas)

PVP	**Plant Variety Protection**
RDP	**Rural Development Project**
RFLP	**Restriction Fragment Length Polymorphism**
RNVP	**National Plant Varieties Register** **(Registro Nacional de Variedades de Plantas)**
SAF	**Secretariat of Agriculture and Development** **(Secretaría de Agricultura y Fomento)**
SARH	**Secretariat of Agriculture and Hydraulic Resources** **(Secretaría de Agricultura y Recursos Hidráulicos)**
SECOFI	**Secretariat of Commerce and Industrial Development** **(Secretaría de Comercio y Fomento Industrial)**
SNICS	**National Seed Inspection and Certification Service** **(Servicio Nacional de Inspección y Certificación de Semillas)**
TABAMEX	**Mexican Tobacco Company** **(Tabacos de México)**
UNAM	**National Autonomous University of Mexico** **(Universidad Nacional Autónoma de México)**
UNDP	**United Nations Development Program**

MEXICO

AGRICULTURAL TECHNOLOGY SECTOR REVIEW

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This report is based on the findings of World Bank missions to Mexico during January and February of 1990. The mission was composed of J. McIntire (LA2AG, mission leader), M. McMahon (LATAG, wheat and maize research), M. Colegrove (consultant, seeds), R. Clifford (LA2C2), J. Barton, (consultant, legal aspects of research), and R. Henson (consultant, grain legumes). The mission acknowledges the essential contributions of INIFAP and other Mexican scientists: Dr. Jorge Acosta Gallegos (grain legumes), Dr. Everardo Aceves Navarro (seeds), Ing. Ernesto Badillo Naverette (research planning and programming), Dr. Francisco Cardenas (genetic resources), Dr. Everardo Gonzalez Padilla (livestock), Dr. Leopoldo Mendoza Onofre (sorghum), Ing. Eduardo Menocal (National Water Commission, tropical livestock), Dr. Raul Mosqueda (tropical fruits), Dr. Joaquin Ortiz (maize), Dr. Mario Salazar (rice and wheat), Dr. Moises Tellez (law and administration), and Dr. Antonio Turrent Fernandez (all aspects). Ms. Sarah Crow assisted in the production of this report. Country Department Director, Rainer Steckhan. Division Chief, Michael Baxter.

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AGRICULTURAL TECHNOLOGY SECTOR REVIEW

EXECUTIVE SUMMARY

A. Background

1. Mexico's public agricultural research has reached a critical point. After much progress over several decades, the impact of research on key commodities has begun to wane. The growth of maize yields is not adequate, that of wheat and sorghum has slowed, and that of beans has virtually halted. Coffee and cotton production, the traditional exports, has risen slowly or fallen. There have been impressive technical changes for some exportable fruits and vegetables--but the output of others has been untouched by public research.

2. This comes at a time of important shifts in Mexico's agriculture. With major changes in land use--the closing of the agricultural frontier; slower, more expensive new irrigation--Mexico must generate technologies to raise yields per unit of land and do so in the tropical and rainfed areas that have benefitted less from past research and extension.

3. The closing of the agricultural frontier in the mid-1960s ended the option of sowing more land, the key source of past growth. Where there is land to bring under cultivation, it may be of poorer quality, raising the investment needed to achieve improved output.

4. More recently, the rising cost and slowdown of new irrigation have put added stress on the rainfed and tropical areas, where development problems are already difficult because of greater variability in precipitation, more fragile soils, and higher pest pressure. The tropics are less able to borrow from the experience and technology of temperate countries, as happened in irrigated Mexico. Compared with richer farmers in irrigated lands, farmers in tropical and rainfed land tend to be poorer, more subsistence oriented and less capable of bearing risk--thus less likely to attract private research and extension programs.

5. Other developments have affected research and extension as well. When highly productive cultivars of cereals and oilseeds became available in the 1950s and 1960s, Mexican adaptive research and extension, plus greater input use, led to swift production gains. For many important crops--sorghum, wheat, soybeans, rice--those stimuli are weaker now and the rate of potential yield increase is slower. National research must reinforce this traditional source of growth or find alternatives.

6. Developments in private research involve the growth of competing domestic and foreign sources of output, novel research techniques, and innovative farming practices. Employing these techniques in Mexico, or importing the products of their use, will require modifications in the national program. Using imported scientific outputs is complicated by the advent of a new legal environment for biological research, an area that may improve incentives for private research in crops traditionally in the public domain.

7. All these challenges occur as the Mexican Government has drastically cut staff and funds for public research and extension as part of reducing the public sector's role in agriculture. As a result, the national program has to redefine itself. The questions it must answer are many. What is the appropriate size and focus of public research and extension? What is the best focus in region, scientific discipline, and commodity? What changes in management and organization of public research and extension agencies will achieve greater impact? What institutional and legal steps in research and extension are needed to restore their contribution to growth? What public policies can encourage greater private contribution? What changes in seed policy and production will improve the generation and transfer of seed-based agricultural technologies? Are there specific barriers to growth in certain key commodities that must be addressed?

Institutions

8. The structure of Mexican agricultural research and extension appears in Figure 1. Most of the focus of this review is on the National Institute for Forestry, Agriculture, and Livestock (INIFAP). This institute and its predecessors have been the center of agricultural technology change. INIFAP is still the main public agency, doing 50-60 percent of national work and receiving nearly all its support from the federal government.

9. INIFAP is divided into 34 state Centers for Crop, Livestock, and Forestry Research (CIFAPs) spread among north, central, and south regions. Research networks in crops, livestock, forestry, and disciplines (for example, weed science and draft animals) provide commodity and thematic organization. Most of INIFAP's work is in applied research, with basic research being important.

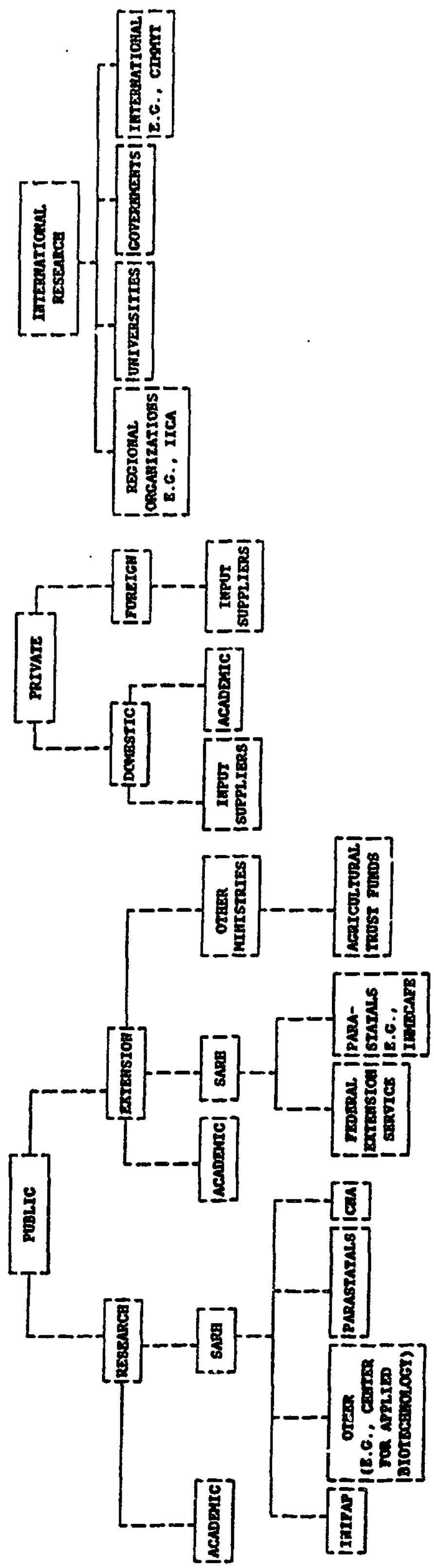
10. Federal parastatals, universities, and a few private organizations provide the other 40-50 percent of the national research program. They conduct basic and applied research, with academic centers doing more basic work than INIFAP. The International Agricultural Research Centers (IARCs) are active, and one, the International Center for Wheat and Maize Improvement (CIMMYT), is headquartered in Mexico. National and international private research involve crop improvement, agricultural chemicals, animal production, veterinary drugs, and agricultural machinery. Private emphasis is on adaptation of foreign technologies, not on basic investigation in Mexico.

11. Extension is provided by the Secretariat of Agriculture and Hydraulic Resources (SARH), the agricultural credit banks, parastatals, and private input suppliers. After soaring in the 1970s, numbers of extensionists have plunged since the mid-1980s. Of the parastatals providing research and technical assistance, the National Commission for Fruit Crops (CONAFRUT), the National Cocoa Development Council (CONADECA), and the Mexican Tobacco Company (TABAMEX) have been dissolved. Recent reforms have sharply reduced the role of the Mexican Sugar Cane Production Institute (IMPA) and the Mexican Coffee Institute (INMECAFE).

B. Why are Public Research and Extension Necessary?

12. Research. The main justification for public agricultural research is that private agents cannot capture all benefits from research. This incentive failure occurs because information about agricultural technology is partly a public good. Agricultural technologies having the character of public goods include some types of crop improvement, agronomic practices, economic investigation, and natural resource management. Because private agents will not provide optimal levels of research, public investment is required in some endeavors if research is to produce significant benefits.

Figure 1. Main Branches of Mexican Agricultural Research and Extension System



13. A second argument for public research is that private agents perceive some risks to be so great that they do not invest adequately. If the riskiness of such research in public terms is less than in private, then government research is again justified. This condition is more likely to be obtained in poor and middle income countries like Mexico where private firms are smaller, less diversified, and so less capable of risk-bearing. Risks are especially large in plant breeding because it has a long product development cycle. They are also significant in crop agronomy, which interacts strongly with highly variable local conditions.

14. A third reason for public research is that some work cannot be imported. This may be the case because little "tradable" research takes place in temperate countries with the most sophisticated scientific systems, or because tropical goods have such variable growing characteristics and product quality. Tropical crops are subject to incentive and risk failures for both foreign and domestic investment, thus they must be improved by national public research. Examples are found in Mexico's highly diverse agroclimate, which allows for many crops--tropical vegetables and fruits, coffee, and cocoa--with sizable growth potential that cannot easily be tapped by simply importing new methods.

15. Extension. Some arguments for public interventions in extension are identical to those in research. Because knowledge about new production methods is partly a public good, the costs of garnering information justify public extension in the same way they justify public research. Firms have no incentive to supply optimal levels of extension because they cannot recover all costs of doing so. But extension is even less likely to be imported than research, because foreign firms will be unwilling to bear the costs of providing services to local farmers, and because such firms assign no value to reducing poverty.

16. There are, however, distinctions between research and extension that create varying degrees of public support to the two activities. One distinction is that public extension makes the distribution of benefits from technical change more equitable. The reason is that economies of scale in procuring knowledge make it cheaper for larger farmers to put it to productive use. Since small farmers find it more expensive to gain knowledge, they may have insufficient incentives to invest in new techniques. Public extension is thus justified, to create more equitable access to new methods.

17. In addition, extension is less risky than research because it typically starts from a base of applicable scientific knowledge. As an example, firms can supply proven inputs (fertilizers and agricultural chemicals) and provide a form of extension via their own marketing without doing any research. This creates a division of labor between activities in which public extension is required (agronomic practices, soil and water conservation) and activities associated with salable inputs, on which private enterprise can supply advice. As a result, the share of public support relative to the total of agricultural research in a country should be expected to be more than the share of public support relative to the total of agricultural extension.

C. Research Impact on Agricultural Productivity

18. The impact of research on agricultural productivity in Mexico has been positive. High rates of return have been calculated in wheat, maize, sorghum, and potatoes. Recent estimates of internal rates of return range from 98 to 119 percent in wheat, and from 77 to 81 percent in maize. Quantitative estimates are not available for rice, forage crops, fruits, or vegetables, but returns to research have clearly been high in those as well.

19. Returns have apparently been highest in irrigated production systems; wheat research is the best example. Returns to rainfed crops appear best in the zones of most reliable rainfall, as illustrated by sorghum and maize. In certain crops the impact of research has been weak; the chief examples are beans, tropical fruits, and vegetables.

20. Despite individual successes, the impact of research on output has been limited. This is apparently because of underinvestment, the inherent difficulty of improving production of important crops such as maize and beans in rainfed areas, and the relatively small area under irrigation (where returns to research are strongest).

D. Barriers to Greater Research Impact on Productivity

1. Funding

21. Lack of money is the main problem in the Mexican national agricultural research system. During the 1970s, Mexico spent between 0.27 and 0.59 percent of its annual agricultural product on public research, a low value in comparison with countries of similar income levels; since the federal budget cuts of the 1980s, it now spends about 0.4 percent, but this is still too low a share. Even adding the contributions of nonfederal public, academic, and private research does not change our conclusion about the lack of money, since comparisons are generally made by counting only central government expenditures on research.

Recommendations

22. Mexico should make it a priority to raise public funding to a level comparable to that of countries with similar income. Since studies world wide show that agricultural research is a profitable public investment, additional expenditure in this area cannot be categorized as a subsidy to unwise investment or to consumption.

23. There are several paths to greater public funding. The obvious one is to transfer public expenditure from untargeted consumption or credit subsidies; the funds reallocated to research would be a small fraction of these unproductive subsidies.

24. A second path is to improve private and state funding of federal research. The potential for private contributions is high (and there are examples of it being tapped successfully); it can be exploited further by creating new farmers organizations (*patronatos*), by strengthening such organizations where they are weak, and by allowing state and local research directors full authority to seek state, international, and private funds, subject only to ex-post financial and scientific audit.

25. A third path is to ensure that other sources--laboratory fees, crop sales, seed sales, plant breeding royalties and licenses--are fully tapped. This can be done by charging market rates for services and commodities, and by reforming the seed law to allow INIFAP to get revenue from its plant breeding efforts. Funds gained from sales of goods and services may be small, since research stations already charge market rates for them. Funds from plant breeding royalties may be substantial though we have no good estimate.

26. A fourth path is to reduce the share of research expenditure on wages and salaries. Obviously, laboratories and research stations cannot function effectively if only wage costs are

covered. However, this reform cannot be achieved by reducing staff and shifting wage savings to material costs, since large staff reductions have already taken place.

2. Efficiency of Resource Use in Public Research

27. The efficiency of a research system has two components: allocative ("studying the right problems") and technical ("getting the most out of resources dedicated to a particular problem"). We measured allocative efficiency with a form of congruence analysis. Technical efficiency was measured by a review of rate of return studies to Mexican agricultural research.

28. If allocations with respect to demand for research output are poor, then the allocative efficiency of research is said to be bad. If allocative efficiency is low, then changes in research priorities can improve the return to government investment. To examine this question, we analyzed measures of research resource allocation with respect to their congruence with region, productive sector, and commodity.

29. Regional priorities (north/center/south). Public priorities were principally in the irrigated north and in the temperate central highlands. In 1976, when spending on agricultural research was highest in relation to the value of agricultural output, half of the crop experimental centers were in the north. From 1978 to 1984, about 35 percent of all experiments took place in the north, 37 percent in the center, and 29 percent in the south.

30. The south apparently benefitted least from public crop improvement. Most varieties released from 1942 to 1985 were for the north and center. Of cultivars released in that period, 43 percent were for irrigated conditions and another one-third were for mixed rainfed and irrigated conditions. Wheat, exclusively an arid/irrigated and temperate crop, accounted for almost 30 percent of all releases. From 1976 to 1985, only 4 maize varieties were released in the south--while 11 were released in the center, and 14 in the north.

31. To test the efficiency of current allocations, congruence analysis was used to compare demand for research output and INIFAP allocations. Crop area and the value of production were used as measures of demand for research; numbers of experiments planned for 1990-94 were used to measure INIFAP allocations. Both indices established that INIFAP's planned allocations were highly congruent with crop area and the value of production--and thus that little apparently could be gained by changing allocations to different states.

32. While INIFAP's allocations are congruent with regional output, they are not fully consistent with the most socially efficient allocation of public resources. This is because private research is weaker in the tropical (and poorer) south. The area's greater environmental complexity makes research and extension costs there higher, which gives private firms less incentive to invest. Results of foreign private research are more easily adapted to the north and center and can be imported there at lower cost than in the south. Farmers in the south are poorer and can contribute less to financing research. We conclude that INIFAP should do more in the tropics.

33. INIFAP's defect is not compensated by other public or academic research. As one example, while there is substantial work in the tropics--including that by the Post-Graduate College, the National Water Commission (CNA), the private livestock sector, and two parastatals (INMECAFE and IMPA)--this work is not in basic food crops or in tropical fruits. The existence of this work does not diminish the need for INIFAP to concentrate more on the tropics.

34. Sector priorities (irrigated/rainfed). The past focus has been on irrigated agriculture, and the best yield gains have been achieved there; but there is high transferability of breeding research (for better yields) under irrigated conditions to rainfed conditions. Therefore--as seen in the wheat, maize, and bean cultivars used in Mexico--such research with irrigation can continue to benefit rainfed areas. The historical congruence between materials developed and systems was admittedly poor, but some of the incongruence was, and still is, compensated for by the transferability of results from irrigated to rainfed sites.

35. However, a shift of research attention to rainfed areas ought to continue. First, there are difficulties in adapting to rainfed conditions those cultivars originally selected with irrigation, because there is greater site-specificity in dryland farming. Second, finding robust drought resistance is more formidable in rainfed areas and it requires local trials. Third, transferring crop management research from irrigated to rainfed areas is not really possible because of interactions with moisture availability. Last, private research is negligible for some rainfed/tropical questions. Private firms are unlikely to study drought or heat tolerance in rainfed/tropical systems because the risks are too high. Such firms will not study cropping practices related to improved cultivars until public agencies have done basic research to develop those cultivars.

36. We asked three main questions about the technical efficiency of the public research system. Is its organization adequate? Does it use appropriate disciplines? Does it devote enough resources to basic research?

37. Organization. INIFAP was created in 1985 by joining the separate centers on crops (INIA), livestock (INIP), and forestry (INIF). Administration by regional centers gave way to administration through the CIFAPs. Research networks permit collaboration within disciplines working on different crops, or in different environments, and across disciplines on common problems.

38. The current organization is appropriate and we recommend strongly that there be no further major changes in the organization of INIFAP; it achieves economies of scale by jointly managing crop, livestock, and forestry. It avoids duplication of common themes--pastures, forage crops, agroforestry, soil fertility, economics and natural resources--in what formerly were the three centers. The structure of state centers, in which the CIFAPs are political units, is more efficient for state and local cost-sharing and for responding to specific problems. The system of research networks permits collaboration within disciplines on common methods and between disciplines on common problems.

39. The CIFAP organization is sometimes criticized for lacking the ecological focus that was imposed by the regional centers of INIFAP's predecessors. This criticism is invalid. Since the location of the centers has, in fact, not changed, experiments are still done in a range of agroclimates. Moreover, INIFAP networks can keep an ecological focus.

40. Changes are needed, however, in the management of the research networks. There are now 46 networks, many of which have too few resources to do anything. Maintaining them is an administrative burden that detracts from scientific work. The number should be reduced by consolidating some networks. Network coordinators should have small federal core budgets, but no administrative responsibility over CIFAP budgets.

41. Disciplinary priorities. Current emphasis is too strong on plant breeding and too weak on crop management. Plant breeding appears to be chosen as a technique for solving all problems, to the detriment of such techniques as adaptive agronomic research. Especially notable is

the insufficient analysis of farm yields. There will always be a gap between experimental and farm yields, but the great yield gaps now observed clearly indicate that not enough adaptive research has been done.

42. Added emphasis on crop management research will require greater input from the economics program within INIFAP. While the quality of economics work in the institute appears very good, its insights are not always well incorporated in the other scientific programs.

43. Basic/applied research. INIFAP has little basic research as such, but it does have access to the research done in Mexican and other universities, and in the international agricultural research centers. The basic component of INIFAP research can be expanded by improving contacts with Mexican universities and by improving resources to the National Disciplinary Research Centers (CENIDs). One suggestion is to make grants to universities for work on basic topics, marginal areas, or in disciplines that are too small for an INIFAP program.

3. Legal Barriers to Private Sector Research

44. Legal and fiscal barriers to private and international activities can hamper initiatives that complements public research. As a result, private research may not replace public research where it has a comparative advantage in doing so.

45. In the case of Mexico, there is little evidence that such barriers have hampered research in the past. The public and private branches of the agricultural research system have been quick to adopt foreign technologies, including machines, chemicals, and intermediate inputs such as germplasm. Major private research and extension activities--defined to include the use of results of foreign research in Mexico--were identified in livestock production, seeds, agrochemicals, and agricultural machinery. The ability to rely on some imported technologies may weaken, however, as research emphasis shifts to rainfed and tropical zones, for which "tradable" technologies are less available.

46. Mexico's strongest legal barriers are those affecting rights to intellectual property and the fiscal and other incentives to invest in research and extension.

47. Intellectual property issues. These issues are three: plant variety protection (PVP), general patent law, and trade secrecy. The outstanding issue has been PVP, which was only recognized in Mexico in June 1991. However, it appears that the absence of PVP did not unduly affect incentives for seed-based research and extension in Mexico. Many genetic materials are hybrids and thus have some inherent biological protection, and firms producing and selling varieties, which lack biological protection, have protected themselves by earning good reputations for quality and reliability of supply. In the future, however, the government's recognition of PVP should improve incentives for the private development or import of single-cross maize hybrids. The patent law of 1991 provides expanded protection

48. Fiscal and other barriers. Other legal and fiscal barriers to private research and extension are not very imposing. The main barrier is the tax-deduction limit (one percent of gross sales) on contributions to research funds. Since one reform in the funding of public research is to seek greater private participation through producers' organizations, this limit ought to be raised.

4. Extension

49. The problems of extension are much like those of research. Resources after the budget cuts of the mid-1980s are too limited. In addition, the extension service has sometimes failed to establish the right priorities, to maintain strong links to research, and to use field staff efficiently.

Recommendations

50. Funding of the extension service. The public extension service ought to be enlarged as it is inadequate to contribute to renewed growth. After expanding in the 1970s, the public extension system--SARH, the agricultural credit banks, and parastatals--has shrunk by about one-third. Even before the cutbacks of the 1980s, the service was too small to achieve the results in rainfed and tropical areas that have been achieved elsewhere with better extension coverage.

51. Reforms in the conduct of extension. Reforms in extension management are a necessity. One reform is to move more staff to rainfed and tropical areas. Congruence of extension staff with the value of production is very good, but the extension activities of input suppliers are better in irrigated zones than in others. The congruence analysis is misleading because it does not count those input-related services. Some shift of the public service to rainfed and tropical zones can thus be justified by the paucity of private input-related activities there.

52. A second reform is greater cost-sharing. This would affect mainly the extension service of SARH and the parastatal for coffee, since better cost-sharing has already begun in the trust funds. While increased cost-sharing is important and should be encouraged, it is inherently limited by the need to provide an implicit extension subsidy to poor farmers. Because of this factor, cost-sharing should be seen as only a partial substitute for more public resources.

53. A third reform is reallocation of extension workers' time. Extension workers spend too much on time administration and statistics and not enough time on technical assistance to farmers. A national survey of extensionists suggests that economies of 10-15 percent could be achieved by reducing the burden of extraneous jobs. This is not a panacea but would be a productive reform.

54. A fourth reform is to provide more training. Many extension workers do not have technical degrees--and with those degrees often lack continued in-service training.

5. Seed Production and Marketing

55. Much of the growth of Mexican agriculture has come from the use of improved crop cultivars. Despite the importance of that source of growth, bad policy has slowed the spread of promising seed-based technologies. The seed system should be altered to reduce government involvement, to improve the efficiency of remaining government activities, and to stimulate more private participation. To achieve those goals, key reforms are needed in market regulation, in the role of the National Seed Company (PRONASE), and in scientific policy affecting the seed industry.

56. Market regulation. Government can choose between a "European" regulatory structure or a "United States" type. In the United States type, farmers' judgments about seed quality govern the industry and there is no public seed certification. Any private firm can sell "certified seed", and viability of a firm depends only on the market test of farmers' use. In a European structure, public agencies certify seed characteristics.

57. Mexico has a European system. The dominant argument for maintaining it is that the risks of relying solely on private judgments about seed quality are great and information may be poor; firms then sometimes have incentives to supply poor seed. A second argument is that public certification affords some protection to producers of new plant cultivars. Without certification, producers may have to seek protection through costly legal means.

58. The role of PRONASE. Whatever regulatory structure is chosen, the government must decide the fate of the public seed company, PRONASE. One argument for a public seed company is that the private sector lacks incentives to produce certain seeds, mainly varieties in which it cannot recover the full costs of development (the "variety argument"). The private sector is also thought to lack incentives to produce seed and to market the seeds in poor, highly variable, areas (the "poor farmer" argument).

59. The variety argument is valid for research, but it is not valid for seed production and marketing. Private companies do sell varieties; they can link superior seed quality and terms of supply to brand names, thus capturing the full returns of their efforts. As a result, the variety argument alone cannot justify a public seed production and marketing company. As much as any private firm, a public firm faces the variety problem, and must solve it by supplying seed of a distinctive quality. PRONASE has not done this. In fact, poor seed quality is the principal farmers' criticism of PRONASE.

60. According to the "poor farmer" argument, a public seed company should supply the poor areas ignored by private firms. It is true that the total costs of seed supply (research, development, marketing) are higher in poor areas--but they are mainly higher in research, in which failures often occur. This fact justifies a subsidy to public research. In seed production and marketing, however, costs are not necessarily greater, thus a subsidy is not necessarily justified to those activities, and an incentive failure would not exist to justify the entry of a public firm where there is no private firm. An equity argument may justify some form of income transfer to private farmers or a general subsidy on inputs, but a subsidy on seed production is not clear.

61. Using the poverty argument to continue subsidies to PRONASE requires a direct link between its activities and poor areas. However, PRONASE's main crop has been wheat, a crop of the irrigated north. If PRONASE continues to exist on poverty grounds, that implies a move out of the north--and a corresponding change in its crop portfolio.

62. Scientific policy. PRONASE now has legal preferential access to INIFAP cultivars. The result of this preference is to exclude private Mexican firms from adapting INIFAP germplasm, and to deprive INIFAP of income from plant breeding royalties. The key reform in the seed law should be to remove this preference, so that all organizations and individuals have equal access to germplasm for plant breeding and seed production. Giving Mexican seed companies better access to INIFAP materials, will allow them to compete better with international firms; the reform may also provide seed royalties and license fees that can be invested in INIFAP.

63. Two other reforms would generate more competition in seed-based technical changes. Responsibility for producing foundation seed from breeder's seed should be transferred from PRONASE to INIFAP and other institutions. Restrictions on international centers releasing germplasm in Mexico should also be eliminated.

6. Relations to the International Agricultural Research Centers

64. The IARCs are important because they provide training, new research methods, access to foreign results, and germplasm for Mexican crop improvement programs. Center contributions vary across crops and regions, but they are clearly vital sources of knowledge for Mexican agriculture.

65. Changes in the priorities of the IARCs, while they do not depend on Mexican national decisions, are analogous to the issues of allocative efficiency within INIFAP. Various criticisms have arisen of the centers' priorities in Mexico with respect to production systems and type of activity.

66. Priorities of the IARCs. The argument has been made that the IARCs could do more in highland tropical and rainfed areas, thereby enhancing their contribution to Mexican agriculture. This is unlikely to be important or practical. The centers' contributions by production system are in fact mainly in rainfed agriculture. In addition, CIMMYT research in rainfed maize, the International Center for Tropical Agriculture (CIAT) work on beans, cassava, and tropical pastures, the International Potato Center's (CIP's) on potatoes, and the International Crops Research Institute for the Semiarid Tropics (ICRISAT's) on sorghum are largely in rainfed systems. With respect to the highlands, CIP's potato work and ICRISAT's cold-tolerant sorghum do concentrate on the higher altitudes. The contribution of the IARCs, therefore, appears congruent with the needs of rainfed and tropical sites. The one major effort in irrigated production is the CIMMYT wheat program.

67. Further reallocation of the IARCs' work to Mexican rainfed areas would be impractical in that it might be inconsistent with the global priorities of individual centers (as determined by the sum of their relations with all partner countries, not just Mexico). Because Mexico is unlikely to affect the IARCs' allocations, the appropriate policy is to allocate Mexican national resources taking into account the centers' existing contributions.

68. Another criticism is that the centers should do more in germplasm bank development. This does not appear relevant in Mexico. There is an International Board for Plant Genetic Resources (IBPGR) program in Mexico that contributes to INIFAP as well as to national universities. The principal effort of the centers in Mexico is through germplasm exchanges; the exchanged materials can be put into Mexican banks. Since it is unlikely that the centers will do more in germplasm, Mexico's policy response should be to raise its own investment while taking into account complementary IARC efforts.

69. Reforms in the national use of IARC resources. The impact of international agricultural research within a host country depends a good deal on the capacity of the national program. The chief barrier to better use of the IARCs in Mexico is lack of funds on the Mexican side (quite a different picture from that in countries with weaker scientific and technical capacity where the IARCs are substitutes for national programs). The main reform is thus to raise Mexican support to the national research system so as to make more efficient use of external scientific contributions.

7. Problems in Individual Commodities

70. In addition to reforms in funding and management, complementary changes are needed in research on Mexico's individual commodities. Those reviewed--maize, wheat, beans,

tropical livestock, and coffee--account for more than half of INIFAP's portfolio and for 60 percent of the agricultural product of the country.

71. Maize. Maize grows in a dozen discrete environments and covers 40 percent of the annual crop area of Mexico. Mexican achievements in maize improvement and agronomy have been good, as measured by rate of return studies and by the steady, if slow, growth of yields over many years. Despite advances, however, output has not kept up with demand. In particular, productivity growth in most of the crop's rainfed environments has been less than that of irrigated agriculture.

72. The main problems confronting maize research are the complexity of production environments, past neglect of hybridization as a desirable characteristic of cultivars for smallholder production, and the relatively weak contribution of the private sector, given maize's importance to Mexican agriculture.

73. The diversity of maize environments makes a successful research strategy particularly complex. In fact, the principal defect of the research/extension system has been the failure to deal with this complexity in the transfer of results of past maize improvement. The indicator of this failure is the very high gap between experimental and farm yields in rainfed areas. When successes have taken place, such as the Plan Puebla and PLANAT, they have not been sustained or spread over wider areas.

74. Finding the explanation for adoption failures must be a priority in continuing maize research. Detailed recommendations have been available for more than 30 years, but farmers often ignore them. While it is customary to blame the extension service for farmer unwillingness, it is hard to see why extension per se should have failed with maize when it succeeded with wheat. Most of the fault rests with the maize technology proposed to farmers. Efforts to improve that technology will require more analysis of limiting factors at the farm level.

75. Remedying the failure to transfer breeding results necessitates more emphasis on crop agronomy in areas of high genetic yield potential. This implies stating regional priorities based on analysis of limiting factors, and then defining appropriate research strategies to lessen the effects of those factors. One example is to orient maize research toward the tropical and subtropical areas where there is less competition from other crops (hybrid sorghum and rainfed wheat). The government has taken a major step with its National High Technology Maize Program (PRONAMAT), begun in 1988.

76. Another shortcoming has been neglect of hybridization strategies in rainfed and tropical areas. This neglect is attributable, apparently, to the belief that poor farmers could not afford to buy hybrid seed every year and that commercial seed supply was too risky for them. Even if this thinking were well-founded, shifting research strategy toward lower-yielding varieties would be inappropriate. If the costs and risks of commercial seeds are excessive, the correct policy is to subsidize seed production and marketing on equity grounds. Mexico should pursue the more productive research direction to maximize yields and use financial incentives to treat the cost/risk problem. More emphasis on hybridization can be part of a strategy of using resources to produce breeding materials for private sector single-cross hybrids in irrigated environments, for single and double-cross hybrids for high potential rainfed environments, and for synthetics and open-pollinated varieties for poorer environments.

77. Private contributions to adaptive maize research and extension have been small. The risks of adapting germplasm have been high, with private firms unable to capture returns to

agronomic and farming systems research. Yet, advances in public research can engender later private initiatives in supply of seeds, fertilizers, and other agricultural chemicals. The public research sector thus should nurture close relations with private input suppliers so as to maximize the benefits of future interactions in adaptive research.

78. INIFAP and other public maize breeding efforts must continue to maintain diversified sources of new germplasm in addition to that available from CIMMYT. Collaborating with Mexican universities, public basic research must turn greater attention to special topics, especially for the tropics and rainfed areas. Where there are commercial materials, public improvement programs have to make more explicit comparisons with them to ensure that the public materials are competitive.

79. Wheat. Wheat research and extension have been the principal successes of Mexico's program. Production impact and economic rates of return to public research have been exceptionally high. Now, however, growth in wheat yield potential has begun to slow, the irrigated crop faces competition for water, and the rainfed crop lags in both potential and actual yield.

80. The main problem in wheat research will be competition from other crops with irrigation. This problem must be dealt with in several ways.

81. First, there must be an expanded effort to raise wheat yield potential. The recent slowing of growth in that potential, the stiffer economic competition from other crops under a more efficient water pricing regime, and the ultimate narrowing of the gap between potential and actual yield--all make it essential that Mexico devote greater resources to wheat research. The contribution of CIMMYT to the Mexican wheat program is sizable, but it cannot substitute for added national resources.

82. A second reform is to concentrate more on efficient water use. This, too, will require added resources--but it will produce results applicable to other crops (rice and vegetables), thus the cost need not be borne by wheat alone. Since water use studies may well conclude that incremental wheat research is uncompetitive, results need to be compared explicitly with proposals justifying greater investment in yield potential work.

83. Another general problem facing wheat research is adaptation in rainfed areas. There have been adoption failures of wheat techniques that appeared to be successful on experiment stations. This argues for more emphasis on economic analysis of experimental results in a yield-gap framework.

84. Rainfed wheats have benefitted from the transfer of irrigated materials and have achieved fast yield growth in the last 15 years. This trend is unlikely to continue for much longer, however, without development of expressly rainfed varieties; there must be greater emphasis on particular traits in rainfed wheats (earliness and drought tolerance). The principal recommended change is to concentrate resources in one location, using others as test sites for material developed at the main location. More work will also be needed on crop agronomy in rainfed systems, since this has also tended to borrow from irrigated.

85. Beans. Beans cover 10-15 percent of the annual crop area and are grown in many environments. Research has developed varieties and corresponding agronomic recommendations for the main types. Despite a long-term research effort and generous financial incentives to producers, bean research has largely failed to have a production impact. The main problems facing bean

research are poor adaptation of improved cultivars, lack of basic researc , and absence of easily adapted international cultivars.

86. Sluggish progress in bean production poses three main issues for future work. First is the widespread failure of introduced varieties to be adopted or, where adopted, to have a great impact. Voluminous work on bean breeding and disease resistance has raised potential yield, but with little effect on farms. While this is true of most major crops in Mexico, beans are a distinctive example. This is partly because beans are grown in some of the poorer farm areas, but it also indicates that more on-farm and adaptive research will be required to produce new technologies for field conditions. The National High Technology Bean Program (PRONAFAT) is attempting to address this problem, and it is one to which INIFAP should give priority. A related issue is the apparent failure of PRONASE to produce some of the better bean varieties released by INIFAP. Those varieties are now used extensively in the 1990 PRONAFAT program, explicitly designed to close the gap between experimental and farm yields.

87. As a second issue for the future, public agencies have to consider the opportunity cost of foregone work on other enterprises. Setting future bean research priorities will have to compare them with other opportunities--crops, livestock, and forestry--in the same environments.

88. A third future issue is the failure of international and private research to help bean production as they have helped maize and wheat production; this suggests some defect in the fundamental research on the crop. While some failure to import and adapt research results is due to the crop's relative lack of importance in much of the temperate world, there is also a worldwide difficulty in raising yields. It may be important, therefore, to allocate more resources to very basic research outside INIFAP, in collaboration with Mexico's universities and institutes.

89. Tropical livestock. Livestock products have made up about 30 percent of the total gross value of Mexican agricultural output since 1950; livestock research is an important share of the public portfolio. The principal area of unresolved research problems and extension is the tropics, where the limiting factors to livestock production are feed availability and quality, the adaptation of improved breeds, and animal disease.

90. Wrong priorities and low primary production are the main problems in public research for tropical livestock. Unlike some crop research, livestock research could be made more efficient by short-term shifts in priorities. The basic reform is to concentrate more on primary production, always limited in the tropics by erratic moisture supply and low soil fertility. While forages are now a major share of INIFAP's work, expansion of work on primary production must continue. This includes both pasture evaluation (particularly of legumes) to find adapted materials, and pasture management issues. It is also urgent to compare new materials to conventional species under farmers' management.

91. Redistribution of existing resources should concentrate personnel and laboratory facilities at fewer sites, with careful analysis of the means and objectives of the CENIDs. All cross-breeding work of Zebu by European types should be put into one station and oriented toward dual-purpose animals. There should also be less research on pigs and poultry, in view of the commercial alternatives and of the low probability of success.

92. Coffee. Coffee is Mexico's largest agricultural export, having replaced cotton some time ago. Output grew through an increase in area, not yield. Though farmer recommendations have

been available since the 1950s for cultivars and agronomic practices, the impact of research has been small.

93. The main problems facing coffee research are two. Coffee is a permanent crop with a long product-development cycle, thus research results take time to manifest themselves. And in Mexico, there is a near-total absence of private contribution to research, a marked contrast with other major coffee-growing countries.

94. The principal recommendation is to merge into one research and extension agency the coffee research program of INIFAP and that of the parastatal INMECAFE. (The government already plans to take production and marketing activities out of INMECAFE and to restrict its activities to research and extension.) This new entity would become a producers' organization, with most of its funding from a growers' levy. The basic argument for public research, especially given the risky and long-term nature of coffee, implies public support to research within such a producers organization.

MEXICO

AGRICULTURAL TECHNOLOGY SECTOR REVIEW

I. INTRODUCTION--THE POLICY CONTEXT

A. Effects of Past Policies

1.01 Until recently, Mexican economic policy discriminated against agriculture. Policy varied--prices of rice and livestock were taxed, those of maize, sorghum, and most inputs were subsidized--but the impact was to lower farm output. The penalty became most severe after the halt in land expansion in the mid-1960s. Public policy also displaced private suppliers of inputs and services by creating subsidized parastatals. This move impeded growth directly by raising input costs and indirectly by reducing incentives for investment in supplying inputs.

1.02 The last two Mexican administrations (1982-88, 1988-present) have tried to redress this discrimination. They have improved general incentives to tradables production by devaluing the exchange rate and by taking other measures to adjust the sectoral terms of trade. They have made agricultural protection lower and more neutral and have dramatically diminished the government's role by selling state enterprises and by breaking legal, trade, and administrative barriers to private initiatives. They have also begun to rationalize remaining public agencies in water supply, seed production, agricultural finance, and other areas by better defining the public and private sectors.

B. Recent Bank Involvement in Mexican Agriculture

1.03 The World Bank has identified the main problems of Mexican agriculture as slow growth and persistent poverty, caused by inadequate private investment, inefficient public investment, and inappropriate resource allocation. The roots of these problems have included ineffective parastatals, misguided domestic price policies, distorted international trade policies, excessive government regulation, and budgets too small for investment but too generous on consumption.

1.04 The Bank has supported initiatives to raise efficiency by directing public expenditure toward more productive investments, eliminating inefficient state enterprises, and targeting public assistance toward the neediest consumers and producers. Examples of such reforms are in trade policy (sectoral adjustment loans), agricultural finance (rural credit operations), irrigated agriculture (a time-slice operation), and poverty alleviation (a regional decentralization and rural development project).

1.05 One remaining target for greater investment and policy reform is the public agricultural research and extension system. Changes in that system would be consistent with the needed shift in public spending--toward investment and away from consumption. This target is in line with other Bank initiatives, but the sector has been somewhat neglected in lending and sector work compared with investments in rural finance or irrigation.

C. Bank Support for Mexican Agricultural Research and Extension

1.06 In the decade after 1975, the Bank's involvement in research and extension was limited to projects (Table 1.1) in rainfed agriculture, irrigation, integrated rural development, and rural credit. There was no major project in agricultural research or extension.

1.07 Rainfed agriculture. The Papaloapan Rural Development Project and the Investment Programs For Rural Development (PIDER) I and II had small or no research components, and extension components of 10-20 percent of the loan amount. PRODERITH I and PLANAT had major research components intended to alter the system's historical slant toward irrigation.

1.08 The goal of PRODERITH was to raise productivity in the humid tropics, mainly by transferring technology. It was successful in a whole-farm approach to research, in building research infrastructure, and in establishing extension links. PLANAT was designed to support rainfed districts, to extend new crop and livestock technologies, to undertake research and on-farm testing of those technologies, and to carry out forestry, rural works, and soil conservation. The project completion report (Report No. 8335-ME) noted successes in the on-farm testing component and positive impacts on commodity output. It attributed the progress to better management of PLANAT districts, superior budget for district infrastructure, and farmer self-help activities with appropriate technical supervision. Successful research took place in crops, livestock, and forestry.

Table 1.1. Mexico--Bank Involvement in Agricultural Research and Extension, 1975-1982
(US$ million at time of effectiveness)

Project		Initial Year	Project Amount	Loan Amount	Research Component	Extension Component
Papaloapan Rural Development	1053-ME	1975	138.5	50.0	-0-	-0-
PIDER I	1110-ME	1975	294.5	110.0	-0-	15.1
PIDER II	1462-ME	1977	255.0	120.0	-0-	10.0
PRODERITH I	1553-ME	1978	149.0	56.0	33.7	16.2
FIRA VI	1968-ME	1978	452.2	200.0	-0-	23.3
FIRA VII	1891-ME	1980	854.0	325.0	-0-	19.6
PLANAT	1945-ME	1981	797.0	280.0	137.3	45.5
Bajo Rio Bravo/ San Juan II	2100-ME	1982	506.0	180.0	-0-	26.7

Source: Word Bank Files.

1.09 Irrigated agriculture. The Bank has substantial experience in Mexican irrigated agriculture. A subsector survey (Report No. 4516-ME, 1983) identified key issues as the need for a strong link between research and extension, water pricing, water use efficiency and the utility of a whole-farm--as opposed to a commodity--approach. As with rainfed projects, key factors in project impact were the intensity of extension and the strength of its research links.

1.10 Rural credit. Bank support to rural credit projects has included indirect financing to extension via the public agricultural trust funds. Emphasis in credit projects has been on funding existing technologies and promoting their use in demonstrations, since it was assumed that they were creditworthy without further research. While much credit was subsidized--thus not an unbiased economic test of methods generated by the research and extension service--there has been an expansion of new techniques, especially fertilizers and machinery, because of the availability of finance.

1.11 Research components of projects under supervision. Research components in projects under supervision are local verification trials or minor infrastructure (Table 1.2). PRODERITH II builds upon its predecessor, and PROCATI provides small amounts for adaptive on-farm research. The Agricultural Technology Project (Loan 3465-ME) provides US$200 million for applied and adaptive research over seven years. No project supports basic research.

Table 1.2. Mexico--Current Bank Involvement in Agricultural Research and Extension
(US$ million at time of effectiveness)

Project		Initial Year	Project Amount	Loan Amount	Research Component	Extension Component
Rio Fuerte/ Sinaloa	1706-ME	1979	249.7	92.0	7.0	8.9
Apatzingan Irrigation/ Rehabilitation	1858-ME	1980	408.8	160.0	-0-	9.8
PIDER III	2043-ME	1981	506.0	175.0	-0-	26.7
San Fernando Agricultural Development	2191-ME	1982	350.0	[illegible]	-0-	5.3
Chiapas Rural Development	2526-ME	1985	181.6	90.0	1.9	21.0
PRODERITH II	2658-ME	1986	217.5	109.0	12.4	20.4
PROCATI	2859-ME	1987	73.8	20.0	3.0	66.6
Forestry	3115-ME	1989	91.1	45.5	-0-	2.0
Agricultural Technology	3465-ME	1992	300.0	150.0	200.0	100.0

Source: World Bank Files.

1.12 Bank involvement in extension. A Bank sector review (Report No. 5255-ME, 1984) indicted the extension system for poor staff training, low salaries, lack of a career path, inadequate response to farmers' needs, limited coordination among agencies, and insufficient operating expenditures. Other issues raised were cost-sharing, extension techniques, and inequality of coverage of rich and poor agroclimates. A pilot Program for Training, Technical Assistance, and Research (PROCATI) was initiated in 1987 to remedy deficiencies identified by the review. PROCATI invests in infrastructure and training and provide operating funds, staff incentives, and a better mechanism to accommodate farmers' needs. The Agricultural Technology Project continues the work of PROCATI in 75 of the 192 rural development districts of the country.

1.13 Lessons learned. The assumption that technology was available led to the exclusion of large research components from past credit and irrigation projects. The thinking was that major investments could succeed with only incremental support from research and extension because adequate methods already existed. Project experience generally confirms that thought, though the effect of subsidized credit on technology adoption has probably been seriously underestimated as a factor. In irrigated projects, there is the additional finding that farmers' organizations are important to the efficiency of extension; they provide means for better information-sharing in the farm community.

1.14 The principal lesson from rainfed projects is that more intensive extension can speed the transfer of technology. Adaptations of existing knowledge can be done well via extension. Examples of positive results in rainfed projects include better yields of wheat, adoption of hybrid maizes, and the rapid rise in fertilizer use. The conclusion that extension/adaptive research affects productivity has justified continuing Bank support to components of PRODERITH II and Chiapas Rural Development.

D. Analytic Issues in Agricultural Research and Extension

1.15 In the context of important reforms in Mexican agricultural policy--and of limited previous involvement of the Bank in Mexican agricultural research--we asked questions about how to obtain greater impact from agricultural research.

(a) Funding: What is the appropriate size of public research and extension? Are current levels of funding adequate? Are there means to improve private financing or self-financing of public research?

(b) Priorities: What are the appropriate priorities for region, commodity, and production system? Would changing priorities improve the return to public research?

(c) Organization and management: Is the organization of the main public research institution adequate? Is its mix of disciplines appropriate? Does it devote enough resources to basic research? What institutional changes in agricultural research and extension can bolster its contribution to growth?

(d) Seed policy: Much of the earlier growth of Mexican crop production resulted from adoption of higher-yielding plant cultivars. As those will continue to be important sources of growth, what reforms ought to be made in seed policy and production to encourage cheaper transmission of new seed-based technologies to producers?

(e) Legal barriers: The government's emphasis on greater private participation in the economy and on a reduced state role is relevant for analysis of the research sector. Are there legal barriers that could be eliminated so as to elicit more private participation in research and extension? What policies affecting intellectual property rights and research investments could encourage private activity?

(f) Commodities: Since few commodities contribute much of the total value of Mexican agricultural output, it is possible that changes in research on those might spur growth. Maize, wheat, beans, tropical livestock, rice, sorghum, tropical fruits, and coffee were analyzed to identify barriers to greater productivity that might be addressed by research and extension.

II. HISTORY OF AGRICULTURAL GROWTH

A. The Agricultural Sector in Mexico

2.01. Value of output. In 1988, agriculture contributed eight percent of Mexico's gross domestic product (Table 2.1). This share has steadily fallen, from 18 percent in 1950. Within agriculture, subsectoral shares have changed little. Crops typically provide 60-65 percent of the sector's output, livestock 32 percent, and forestry, fishing, and hunting the rest. Within the crop subsector in 1985, cereals accounted for 48 percent, oilseeds for 5 percent, fruits, vegetables, and legumes for 28 percent, sugar cane for 5 percent, fibers for 4 percent, and coffee and cocoa for six percent.

2.02. Regional distribution of output. Mexico's regions differ sharply in patterns of output. Irrigated crops provide 48 percent of the national value of output, but are 80 percent of that value in the north, 50 percent in the center, and 10 percent in the south. The north grows nearly all the wheat, most of the temperate vegetables, oilseeds, cotton, and irrigated maize. The center grows much of the rainfed maize and sorghum, and irrigated crops (sorghum, maize, vegetables) are found in the high valley known as the Bajio. Tropical crops and livestock dominate in the south.

2.03. Input use. Chemical fertilizers and machinery have been replacing agricultural labor since 1950. Fertilizer use grew nearly 50 times from 1950 to 1987 and about 20 times per unit of harvested land. Total tractor use grew by 90 percent between 1965 and 1985 and rose 30 percent per unit of harvested land. While the total agricultural labor force grew by about 26 percent from 1950 to 1985, it fell by roughly 45 percent per hectare.

B. Sources of Growth

2.04. Growth comes from three sources: expanding the use of productive inputs and primary factors, shifting the cropping pattern from less to more productive crops, and increasing the productivity of inputs and factors. The period from 1940/45 to 1960/65 saw expansion of input and primary factor use without major productivity gains. Beginning in the mid-1960s, there were some sharp increases in the productivity of individual crops but with slower overall growth. The cultivated area stopped growing and labor moved from agriculture into other sectors.

2.05. Growth from 1940 to 1965. Agricultural growth was slow until 1930 because of revolutionary disturbances, but became rapid after 1945. The sector's growth rate was 4.6 percent from 1940-64 while overall GDP growth was about 6.5 percent. Crops grew at a rate of 5.0 percent annually, livestock output at 2.6 percent, and forestry at 3.9 percent.

Table 2.1. Gross Internal Product: Total, Agriculture by Sectors and Nonagriculture: 1950-1991
(Billions of Constant Pesos--1988)

Year	Crops	Animal	Forestry	Fisheries and Hunting	Total	Non-Agriculture	Total Economy	Implicit Prices: Agri-culture	Implicit Prices: Nonagri-culture	Implicit Prices: Total
	AGRICULTURAL SECTOR							IMPLICIT PRICES		
		Current Prices								
1950	6,013	2,985	427	93	9,518	43,485	56,505	0.001031	0.000744	0.000746
1955	7,372	3,965	484	54	11,875	57,820	72,412	0.001546	0.001240	0.001244
1960	9,355	5,039	558	210	15,162	82,110	98,782	0.001804	0.001612	0.001617
1965	12,177	4,845	700	178	17,900	121,461	143,355	0.002319	0.001860	0.001865
1970	11,647	7,212	835	308	20,002	165,608	188,020	0.002706	0.002356	0.002363
1975	14,017	8,316	1,182	380	23,895	231,726	252,729	0.005154	0.004216	0.004353
1980	16,810	9,362	1,444	948	28,564	330,829	359,439	0.012885	0.012399	0.012436
1985	19,661	9,609	1,862	1,163	32,293	363,094	395,718	0.133359	0.118661	0.119761
1986	20,245	8,361	1,576	1,243	31,425	349,301	380,909	0.237598	0.206324	0.208805
1987	20,842	8,138	1,451	1,426	31,857	355,471	387,355	0.528154	0.497582	0.500062
1988	18,710	8,792	1,687	1,420	30,609	362,106	392,715	1	1	1
1989	17,997	8,087	1,792	1,444	29,320	375,813	405,089	1.324958	1.257781	1.262778
1990	NA	NA	NA	NA	30,318	390,635	420,896	1.955032	1.560074	1.588733
1991	NA	NA	NA	NA	32,288	405,044	437,292	2.294679	1.880719	1.911454

Note: Price indexes for agriculture, nonagriculture, and the total economy were utilized to transform current values in constant values.

Sources: World Bank estimates based on INEGI, Cuentas Consolidades de la Nacion: Oferta y Utilizacion; PIB 1, Edicion 1986, Tables 3.11 & 4.1, INEGI, Sistema de Cuentas Nacionales de Mexico.

2.06. Roughly 58 percent of output growth in constant prices was due to the expansion of cultivated area; 42 percent was done to better yields. Crop yield growth was more important in 1939-49, and area more important in 1949-59 (Table 2.2). Since irrigated area grew more rapidly than total area and achieved higher yields per unit of land, some of the gain attributable to yields reflects a shift of land from rainfed to irrigated.

Table 2.2. Growth of Value of Output, 1939-59
(Annual %)

	Total Value	Value from Crop: Area	Value from Crop: Yield
1939-49	6.46	2.45	4.01
1949-59	3.68	3.42	0.26
1939-59	5.05	2.92	2.13

Source: Hicks, The Agricultural Development of Mexico, p. 32.

2.07. Crop-specific sources of growth in the quantity of output are shown in Table 2.3. Area expansion was more important in maize, beans, sugar cane, and coffee; yield growth in cotton and wheat. The last two were relatively new crops, wheat being largely unknown before higher-yielding varieties were introduced in the 1950s.

Table 2.3. Components of Changes in Quantity of Output 1949/51 - 1964/66

	Area %	Yield %	Interaction %
Maize	51.7	29.8	18.5
Beans	45.5	20.5	34.0
Cotton	2.1	93.8	4.1
Wheat	7.2	83.4	9.4
Sugar cane	74.4	12.4	13.2
Coffee	58.6	22.6	18.8

Source: Venezian and Gamble, The Agricultural Development of Mexico, p. 94.

2.08. The analysis in Table 2.3 does not support the idea that poorer marginal land was being brought into cultivation; if it did, the interactions term would be negative.

2.09. Changes in the cropping pattern from less to more productive crops were not important. The national cropping pattern, as measured by the shares of different crops in area, changed only slightly from 1950 to 1964 (Table 2.4).

Table 2.4. Changes in National Cropping Pattern, 1950-54 - 1980-85

	Maize	Wheat	Sorghum	Barley	Rice	Soybean	Safflower	Sesame	Coconut	Sunflower	Beans	Chickpeas
Averages, hectares												
1950-54	4,620.1	666.6	0.0	232.0	95.3	0.0	0.0	172.5	33.0	0.0	998.0	115.2
1960-64	6,528.3	812.3	165.0	222.0	138.0	19.8	33.5	234.0	79.2	0.0	1,683.7	138.4
1970-74	7,349.4	720.3	1,071.2	219.7	156.6	214.9	205.8	265.4	127.9	15.2	1,764.1	227.0
1980-85	6,915.0	897.1	1,565.3	280.3	143.6	334.2	315.0	165.5	159.2	10.8	1,811.3	160.3
Shares of total, %												
1950-54	53.1%	7.7%	0.0%	2.7%	1.1%	0.0%	0.0%	2.0%	0.4%	0.0%	11.5%	1.3%
1960-64	52.6%	6.5%	1.3%	1.8%	1.1%	0.2%	0.3%	1.9%	0.6%	0.0%	13.6%	1.1%
1970-74	49.7%	4.9%	7.2%	1.5%	1.1%	1.5%	1.4%	1.8%	0.9%	0.1%	11.9%	1.5%
1980-85	44.8%	6.1%	10.3%	1.8%	1.0%	2.3%	1.9%	1.0%	1.0%	0.1%	11.5%	1.0%

	Pineapple	Mango	Lemon	Oranges	Plantain	Avocado	Strawberry	Melon	Watermelon	Apples	Grapes
Averages, hectares											
1950-54	5.1	8.2	11.0	60.4	37.8	8.0	0.8	5.8	8.1	5.3	[illegible]
1960-64	8.2	8.7	15.8	76.0	63.7	9.2	5.6	19.6	27.1	8.7	12.2
1970-74	8.4	25.3	43.1	157.6	73.5	26.9	6.6	17.6	25.6	28.2	22.4
1980-85	10.5	67.2	64.9	165.9	73.7	59.3	4.5	24.0	32.4	48.1	54.8
Shares of total, %											
1950-54	0.1%	0.1%	0.1%	0.7%	0.4%	0.1%	0.0%	0.1%	0.1%	0.1%	0.1%
1960-64	0.1%	0.1%	0.1%	0.6%	0.5%	0.1%	0.0%	0.2%	0.2%	0.1%	0.1%
1970-74	0.1%	0.2%	0.3%	1.1%	0.5%	0.2%	0.0%	0.1%	0.2%	0.2%	0.2%
1980-85	0.1%	0.5%	0.4%	1.0%	0.5%	0.4%	0.0%	0.2%	0.2%	0.3%	0.4%

	Red Tomato	Green Chili	Dry Chili	Potatoes	Cotton	Henequen	Alfalfa	Forage Barley	Forage Maize	Sugar Cane	Coffee	Cocoa
Averages, hectares												
1950-54	59.6	16.7	21.4	30.9	820.8	144.9	53.1	0.0	0.0	212.3	182.1	30.6
1960-64	61.5	37.3	23.9	46.8	827.1	184.2	98.2	0.0	0.0	375.8	319.7	68.1
1970-74	65.8	50.9	23.2	51.0	479.2	192.6	173.2	2.7	0.0	497.3	367.0	79.1
1980-85	62.4	50.6	22.8	70.5	292.5	129.7	239.0	17.9	92.7	531.5	508.9	64.9
Shares of total, %												
1950-54	0.7%	0.2%	0.2%	0.4%	9.4%	1.7%	0.6%	0.0%	0.0%	2.4%	2.1%	0.4%
1960-64	0.5%	0.3%	0.2%	0.4%	6.7%	1.5%	0.8%	0.0%	0.0%	3.0%	2.6%	0.5%
1970-74	0.4%	0.3%	0.2%	0.3%	3.2%	1.3%	1.2%	0.0%	0.0%	3.4%	2.5%	0.5%
1980-85	0.4%	0.4%	0.1%	0.5%	1.8%	0.8%	1.5%	0.1%	0.6%	3.4%	3.2%	0.4%

2.10. The expansion of output was caused not by higher factor productivity, but by use of more inputs. Estimates of the rates of growth in the use of individual inputs and primary factors before 1965 are given in Table 2.5. Crop land grew at a compound annual rate of 2.0 percent, and agricultural labor at a rate of 3.3 percent. Consumption of variable inputs, power, and implements all grew much more rapidly.

Table 2.5. Compound Annual Rates of Change in Inputs (%), 1940-65

	1940-53	1954-65	1940-65
Primary Factors			
Land	2.2	1.2	2.0
Family Labor	4.0	2.3	3.3
Variable Inputs	6.5	9.2	8.4
Livestock	1.9	1.9	2.4
Power and Implements	6.7	2.4	4.9

Source: Hertford, Sources of Change in Mexican Agricultural Production, p. 17.

2.11. Factor productivity caused little of the growth: nearly all was due to input and primary factor use (Table 2.6).

Table 2.6. Analysis of Total Factor Productivity-- Compound Annual Changes in Input Contributions to Output (%)

	1940-53	1954-65	1940-65
Primary Factors			
Land	0.5	0.5	0.5
Labor	2.3	0.2	1.3
Variable Inputs	0.7	1.6	1.2
Livestock	0.5	0.5	0.7
Power and implements	0.8	0.3	0.6
Total Input	4.7	3.3	4.2
Total Output	4.7	3.7	4.6
Total Factor Productivity	0.0	0.6	0.4

NOTE: The table contains rounding errors. The values are those of Table 2.5 multiplied by the share of each input in the total cost of inputs, using shares estimated with statistical production functions. Source: Hertford, Sources of Change in Mexican Agricultural Production, p. 18.

2.12. The contribution of irrigation. Irrigation was a major source of the post-World War II expansion. Productivity indices for 37 crops from 1946 to 1962 show that cropped area within irrigated districts grew at a compound rate of 8.4 percent and yields at 3.6 percent. Outside irrigated districts, area grew at 1.3 percent and yields at 1.8 percent. The effect of better water supply was reinforced by lower input prices within irrigated districts, apparently because of economies of scale in distribution and better road access.

2.13. The other important characteristic of past expansion of Mexican agriculture was the rapid adoption of mechanization as labor left the sector for higher wages elsewhere. This took place with little public support in research or in extension, but was stimulated by public credit.

2.14. In the period before 1960 for which we have data, therefore, area expansion, in part through public investment in irrigation, was most important in raising agricultural production. After 1950 this expansion was associated with greater wheat yields (the result of research producing higher-yielding varieties and of increased fertilizer use on those varieties), but not with significantly higher yields of other crops. Cultivation also spread to areas that had not been cropped before or had been pastures. There were some changes in regional specialization, associated with development of high-yielding varieties (HYVs) of wheat in the north Pacific region.

2.15. These findings are consistent with those of Ardito-Barletta, who summarized the history of productivity growth this way:

a. Changes in the location of production raised productivity by adding new irrigated lands and new lands in the humid tropics.

b. Irrigation, fertilizer, seeds, and machines explain 25-50 percent of productivity gains from 1940 to 1962.

c. Individual crop gains caused changes in productivity, not changes in cropping pattern; in fact, had individual crop yields not grown, aggregate yields would have fallen as the result of shifts to a cropping pattern with lower-yielding crops.

2.16. 1960 to the present. Beginning in the mid-1960s, agricultural growth began to fall. This drop was associated with slower expansion of total cropped area, as shown in Figure 2. The aggregate area growth rate was 0.3 percent from 1966 to 1985, compared with 2.8 percent from 1950 to 1965, while the rate of irrigated area expansion fell from 3.4 percent to 2.1 percent.

2.17. Sources of slackening growth were identified by analyzing changes in the value of output for 15 major crops from 1960 to 1988 (Table 2.7). The total value of production was defined as the product of crop area, crop yield, and real producer price. For maize, area expansion was most important until the end of the 1960s, at which time growth of national cropped area halted. The picture was similar for wheat, but area even declined in the 1960s with increasing use of modern varieties. For sorghum, area and yield grew rapidly after the original introduction of hybrids in the late 1950s.

2.18. While yields grew more quickly for some crops after 1965, those gains were insufficient to counter the failure of area to grow. Of the five major crops producing faster yield growth in the latter period--maize, barley, rice, sugar, and cocoa--only barley grew more rapidly on aggregate. Of the seven crops with slower yield growth, wheat, sorghum, soybeans, beans, and alfalfa grew more rapidly in the latter period.

Table 2.7. Changes in the Value of Output for 15 Major Crops, 1960-88

MAIZE	Area	Yield	Price	Share	VALUE Interaction
(60-69)	38%	35%	-6%	-1%	73%
(70-79)	8%	17%	-14%	-8%	-0%
(80-88)	6%	40%	7%	-8%	46%

WHEAT	Area	Yield	Price	Share	VALUE Interaction
(60-69)	38%	91%	-29%	-25%	39%
(70-79)	8%	50%	-25%	-16%	3%
(80-88)	6%	22%	-15%	26%	39%

SORGHUM	Area	Yield	Price	Share	VALUE Interaction
(60-69)	38%	67%	-16%	1209%	2426%
(70-79)	8%	19%	2%	170%	254%
(80-88)	6%	12%	-4%	30%	48%

BARLEY	Area	Yield	Price	Share	VALUE Interaction
(60-69)	38%	14%	10%	-29%	23%
(70-79)	8%	75%	-14%	2%	65%
(80-88)	6%	30%	-1%	2%	40%

RICE	Area	Yield	Price	Share	VALUE Interaction
(60-69)	38%	23%	4%	-1%	75%
(70-79)	8%	21%	-2%	6%	37%
(80-88)	6%	24%	-19%	-13%	-7%

SOYBEAN	Area	Yield	Price	Share	VALUE Interaction
(60-69)	NA	NA	NA	NA	NA
(70-79)	8%	-8%	8%	323%	353%
(80-88)	6%	4%	-8%	32%	34%

CARTAMO	Area	Yield	Price	Share	VALUE Interaction
(60-69)	NA	NA	NA	NA	NA
(70-79)	8%	1%	0%	276%	313%
(80-88)	6%	-34%	-27%	-11%	-55%

COTTON SEED	Area	Yield	Price	Share	VALUE Interaction
(60-69)	38%	54%	-3%	-38%	29%
(70-79)	8%	28%	14%	-51%	-23%
(80-88)	6%	7%	-30%	-38%	-51%

BEANS	Area	Yield	Price	Share	VALUE Interaction
(60-69)	38%	32%	4%	15%	119%
(70-79)	8%	24%	14%	-18%	26%
(80-88)	6%	4%	-3%	7%	13%

CHICKPEA	Area	Yield	Price	Share	VALUE Interaction
(60-69)	38%	15%	5%	-7%	56%
(70-79)	8%	13%	22%	25%	86%
(80-88)	6%	-19%	-13%	-35%	-51%

SUGAR CANE	Area	Yield	Price	Share	VALUE Interaction
(60-69)	38%	15%	1%	33%	111%
(70-79)	8%	7%	-3%	7%	20%
(80-88)	6%	3%	44%	-4%	50%

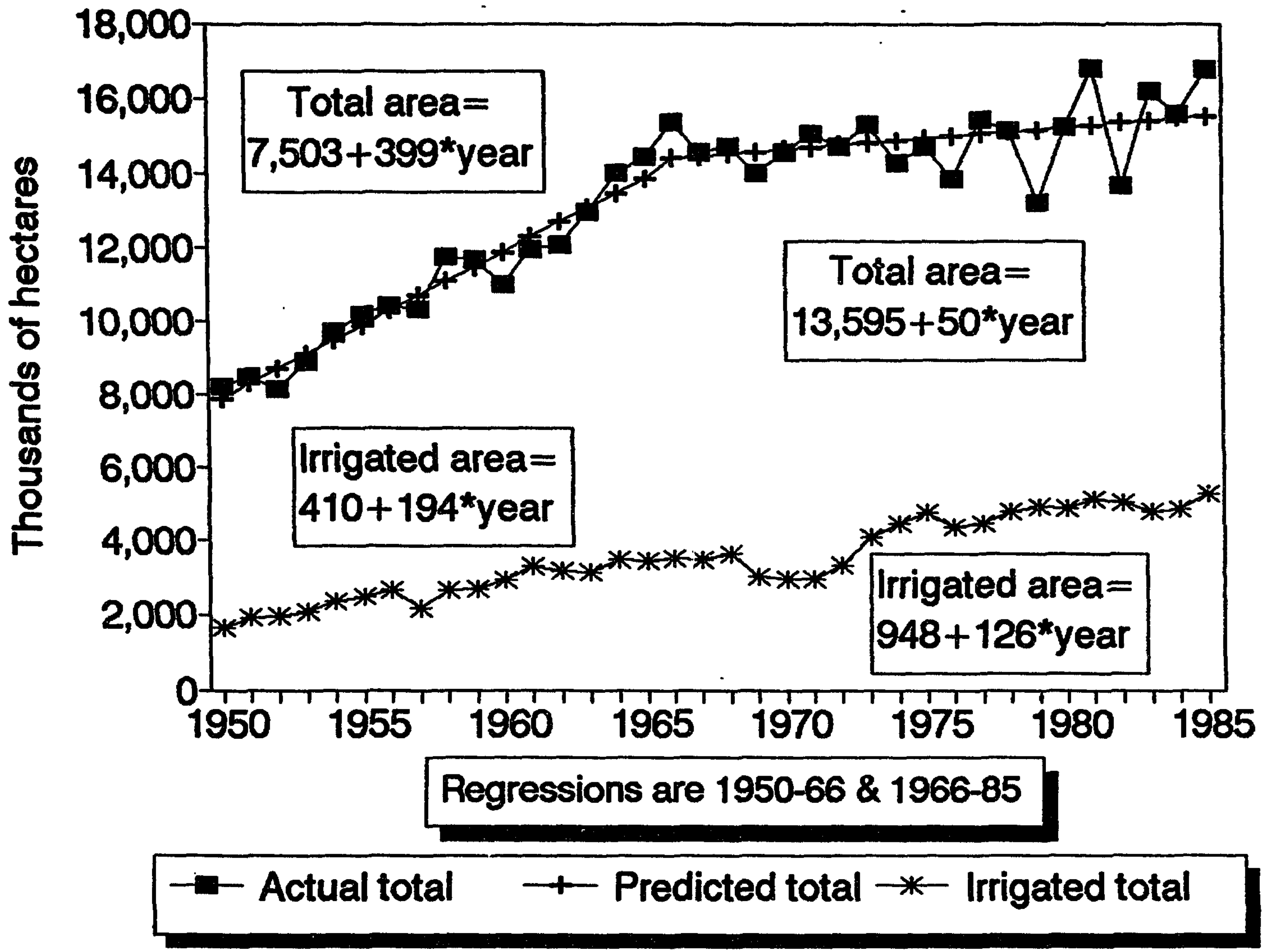
COTTON FIBER	Area	Yield	Price	Share	VALUE Interaction
(60-69)	38%	56%	-35%	-38%	-13%
(70-79)	8%	34%	9%	-51%	-23%
(80-88)	6%	4%	-31%	-38%	-54%

COFFEE	Area	Yield	Price	Share	VALUE Interaction
(60-69)	38%	21%	-29%	12%	32%
(70-79)	8%	15%	18%	3%	52%
(80-88)	6%	24%	-21%	36%	41%

COCOA	Area	Yield	Price	Share	VALUE Interaction
(60-69)	38%	10%	-29%	31%	41%
(70-79)	8%	22%	31%	-2%	71%
(80-88)	6%	36%	-33%	-12%	-16%

ALFALFA	Area	Yield	Price	Share	VALUE Interaction
(60-69)	38%	20%	19%	18%	132%
(70-79)	8%	25%	-21%	63%	74%
(80-88)	6%	-10%	-4%	21%	10%

Figure 2. Annual crop area, 1950-1985



2.19. The share of fibers (cotton and henequen) has plummeted and shares of forages and oilseeds have grown. Little change appears for cereals and grain legumes. There has been a rise in sorghum with a corresponding fall in maize, probably reflecting substitution of the new higher-yielding sorghum for maize in some areas. Growth of area and/or yields has generally been independent of changes in cropping patterns.

2.20. The growth of irrigated area has slowed since the mid-1960s. The estimated annual increment was 198,000 hectares from 1950 to 1965 and fell to 126,000 from 1966 to 1985. Preliminary indications are that it fell to about 84,000 hectares during 1986-88. As important, the growth rate of the yield index on public irrigation districts fell from seven percent before 1965 to less than two percent thereafter (Figure 3).

C. Effects of Research

2.21. Many analyses have confirmed that the rate of return to agricultural research is greater than the opportunity cost of public funds. While rate of return studies are most well-known for wheat and rice, their results have been verified for maize and poultry, as well as for minor crops such as millet and sorghum. The Consultative Group on International Agricultural Research (CGIAR) Impact Study also reported positive effects of research with beans and potatoes.

2.22. The earliest study in Mexico was that of Ardito-Barletta, who reviewed the growth of wheat, maize, sorghum, and potatoes from 1940 to 1964 (Table 2.8), as influenced by agricultural research. He found:

a. The impact of wheat and maize research was apparently achieved via a positive and stable productivity effect of new varieties in wheat and maize, though it was not possible to separate the effects of fertilizer from wheat varieties.

b. There were positive rates of return for public research in maize, wheat, sorghum and potatoes.

c. Wheat showed higher returns than maize because of the latter's slower adoption caused by greater location specificity.

d. Returns could not be measured for beans, livestock, barley, vegetables, and forage crops.

Figure 3. Area and yield indices,
irrigated districts, 1950 - 1987

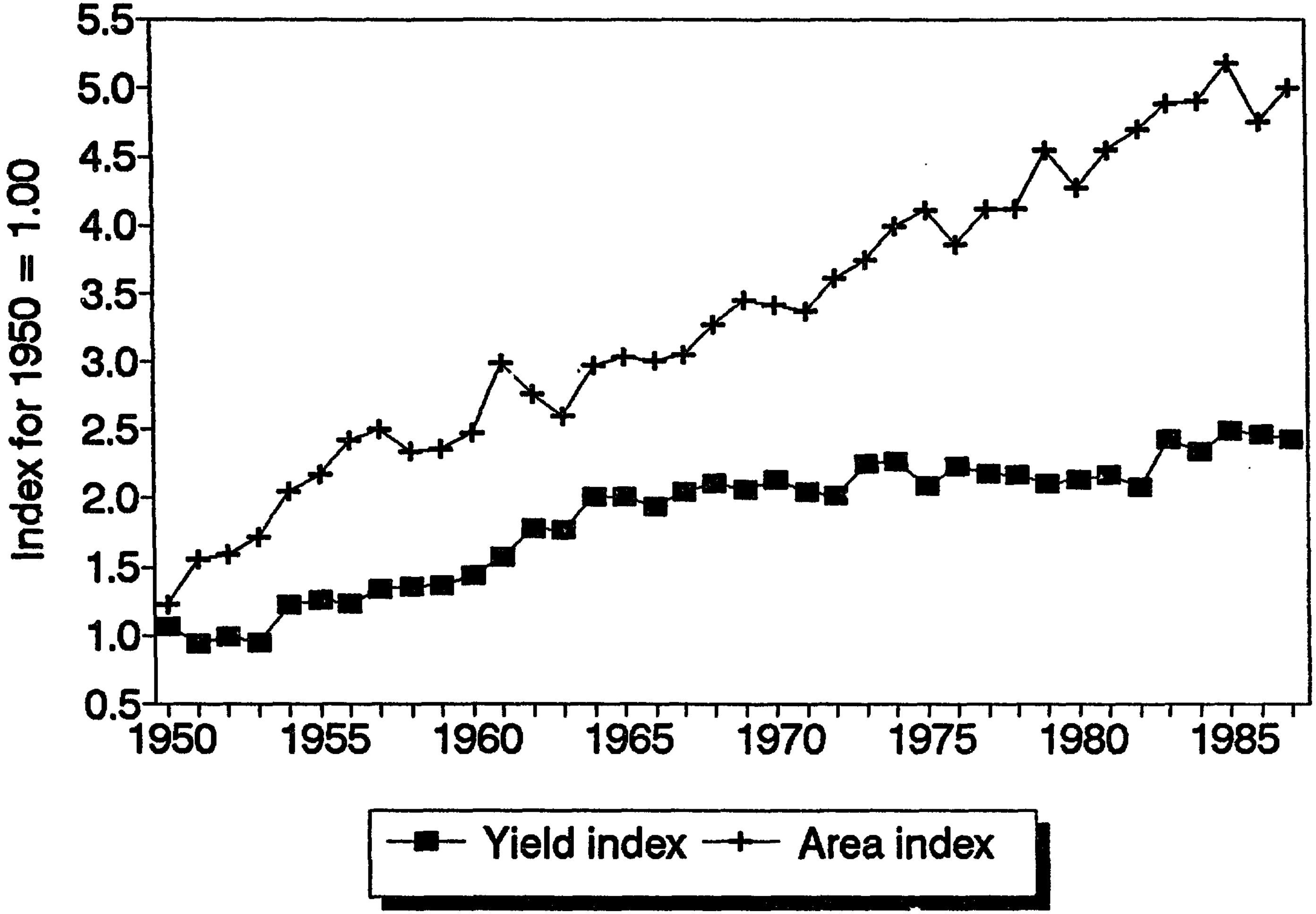


Table 2.8. Returns to Public Agricultural Research in Mexico

Source	Crops	Period	Rate of Return
Ardito-Barletta	wheat,	1940-65	78-104%
	maize and sorghum,	1926-59	
	potatoes		69%
Puente	several farms > 5 ha	1961-69	770%
	several farms < 5 ha	1961-69	21%
	ejidos	1961-69	1066%
	national	1961-69	150%
Becerra and Gonazlez	wheat	1961-87	119%
	wheat	1970-87	98%
Ruvalcaba and Gonzalez	maize	1961-85	77.6-81.3%

Sources: Ardito-Barletta, Cost and Social Benefits of Agricultural Research in Mexico, 1971; Arturo Puente Gonzalez, Evaluacion de la productividad de los insumos y del efecto de la investigacion agricola en la agricultura nacional, 1983; Becerra Marquez and Gonzalez Estrada, Evaluacion economica de la investigacion del INIA en el cultivo del maiz en Mexico, n.d.; Ruvalcaba Limon and Gonzalez Estrada, Evaluacion economica del mejoramiento genetico del trigo en Mexico, 1986.

2.23. Ruvalcaba and Gonzalez (1986) recently estimated internal rates of return to be more than 75 percent for INIA/INIFAP research in maize. Becerra and Gonzalez (ND) found returns greater than 100 percent for wheat. These estimates do not appear to include costs of research done at international agricultural centers and may thus be overestimates.

2.24. Puente studied the aggregate impact of research on farm productivity. While his estimates of returns to research on large farms and for ejidos are aberrantly high, even much lower values would be positive. His estimate for national returns is reasonable, if one considers that it does not include costs of research outside INIA, such as that done in the Mexican universities and technical centers and at CIMMYT.

2.25. Investment in Mexico's agricultural research was highly profitable from the 1950s until very recently. This investment has had only a limited impact on the sector's productivity, however. The most important commodities, maize and beans, benefitted less from crop improvement investigations than from area expansion and later from higher yields due to fertilizer use. The commodity with the greatest research achievements--wheat--is inherently limited in the area where it can be grown with irrigation. Rainfed wheat production has only recently begun to rise rapidly. Finally, research has had little effect in the tropics, for it has been more difficult to raise yields there.

III. HISTORY OF AGRICULTURAL RESEARCH

3.01 This chapter briefly outlines the history of research in crops and tropical livestock. Specific discussion of INIFAP appears in Chapter 5.

3.02 Mexican agricultural research began in 1907 with the creation of a central station at the national agricultural and veterinary school. In 1908, experimental sites were started in Tabasco, San Luis Potosi, and Oaxaca. By 1932, the federal Secretariat of Agriculture and Development (SAF) had set up nine experiment stations. In 1940, the SAF established the Institute of Agricultural Research (IIA), whose mandate was to work on wheat, maize, beans, cotton, rubber, coffee, and cocoa. In 1943, the SAF founded the Office of Special Studies (OEE) in collaboration with the Rockefeller Foundation. The OEE was responsible for research on maize and wheat and, later, beans (1949), potatoes (1952), vegetables (1953), sorghum, barley, forage legumes, and pastures (1954).

3.03 In 1960-61, the federal government established INIA, joining the resources of the IIA and the OEE. (At about the same time, centers for livestock--INIP--and for forestry--INIF--were also created.) INIA was organized into north, center, and south regions with 7 regional centers, 28 experimental stations, and many small substations. By 1976, there were 8 regional centers and 44 stations; by 1981, there were 11 and 56.

3.04 Regional and thematic priorities of INIA. From the limited available information, we can construct a general picture of INIA's work. INIA physical plant was initially in the center and north. In 1961, 11 stations were in the north, 13 in the center, and 6 in the south. Of the 44 stations in 1976, 22 were in the north, with 11 in each of the other two regions.

3.05 We have no information about INIA's experiments in the 1960s. Data for 1978-84 shows that 44 percent of crop experiments were done under irrigated conditions (Table 3.1). Experiments were evenly split among the three regions: 35 percent in the north, 36 percent in the center, and 29 percent in the south. We have no data on the type of those experiments so we can make no conclusions about the disciplinary content of INIA's activities.

3.06 Detailed budget records are scarce but suggest that the north was well-funded compared with the center and south. Of the 1976 budget of Mex$350 million (about Mex$74 billion in 1988 pesos), 17 percent was allocated to the central offices, 42 percent to the north, 25 percent to the center, and 16 percent to the south. The average budget per experiment in the south was 0.46 of the north average and 0.79 of the center average.

3.07 The output of INIA was largely in crop improvement and in collateral recommendations for soil fertility, pest control, and irrigation. While by 1978-84 INIA had begun to work more on the southern tropics, the record of achievements, compiled in 1976, was in temperate crops for the northern, irrigated zones of the country.

Table 3.1. Numbers of Experiments Conducted by INIA by Region and System, 1978-84

	Numbers											
	North			Center			South			National Totals		
Year	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Rainfed	All
1978	1,370	568	1,938	602	1,375	1,977	207	1,282	1,489	2,179	3,225	5,404
1979	874	455	1,329	562	1,080	1,642	211	1,269	1,480	1,647	2,804	4,451
1980	2,520	680	3,200	1,209	1,808	3,017	476	1,954	2,430	4,205	4,442	8,647
1981	1,759	1,714	3,473	1,325	2,428	3,753	1,003	1,574	2,577	4,087	5,716	9,803
1982	1,819	1,291	3,110	1,298	1,769	3,067	1,136	1,477	2,613	4,253	4,537	8,790
1983	2,058	687	2,745	910	1,683	2,593	434	1,720	2,154	3,402	4,090	7,492
1984	1,218	1,193	2,411	794	1,811	2,605	932	1,398	2,330	2,944	4,402	7,346
Average	1,660	941	2,601	957	1,708	2,665	628	1,525	2,153	3,245	4,174	7,419

	Shares										
	North		Mexico	Center		Mexico	South		Mexico	Total	
1978	71%	29%	36%	30%	70%	37%	14%	86%	28%	40%	60%
1979	66%	34%	30%	34%	66%	37%	14%	86%	33%	37%	63%
1980	79%	21%	37%	40%	60%	35%	20%	80%	28%	49%	51%
1981	51%	49%	35%	35%	65%	38%	39%	61%	26%	42%	58%
1982	58%	42%	35%	42%	58%	35%	43%	57%	30%	48%	52%
1983	75%	25%	37%	35%	65%	35%	20%	80%	29%	45%	55%
1984	51%	49%	33%	30%	70%	35%	40%	60%	32%	40%	60%
Average	64%	36%	35%	36%	64%	36%	29%	71%	29%	44%	56%

Source: SARH/INIFAP, Reunion Nacional de Analisis y Perspectivas del Sistema de Investigacion de la SARH, 1988.

3.08 Most varieties released from 1942 to 1985 were for the north and center (Table 3.2). One third of materials released were for mixed rainfed and irrigated production, 43 percent were for irrigated, and less than one quarter were for rainfed (Figures 4 and 5). Wheat, maize, and beans accounted for 71 percent of the total, with wheat almost 30 percent of all released materials.

3.09 Livestock research before the creation of INIP. In 1907 the Federal Government established the Estacion Experimental Agricola de los Jacintos (Federal District) as an annex to the National Agricultural and Veterinary School (Escuela Nacional de Agricultura y Veterinaria). In 1940 the Livestock Institute (Instituto Pecuario) was organized and the Directorate of Experimental Fields (Direccion de Campos Experimentales) established as part of the SAF, the equivalent of the present SARH.

3.10 In 1947 an outbreak of Foot and Mouth Disease (FMD) prompted the Federal Government to create a diagnostic laboratory and a vaccine production unit, which ultimately became the Central Veterinary Diagnostic Center. These activities of the Federal Government were expanded in 1970 under the control of the Animal Health Department, creating a national network of 108 diagnostic laboratories.

3.11 The focus of livestock research was on improved breeds of cattle to cross with the criollo population, on animal health, and on the control of animal pests. Some effort went into to classifying forages and identifying toxic plants. The Livestock Institute was also involved in importing cattle to improve local breeds. In 1947, the Livestock Institute was renamed Directorate of Livestock Research, and in 1962 the Centro Nacional de Investigaciones Pecuarias was created.

Table 3.2. Varieties of Major Crops Released by INIA, 1942-1985

	Region																	
	NORTH						CENTER						SOUTH					
	Before 61	61-65	66-70	71-75	76-80	81-85	Before 61	61-65	66-70	71-75	76-80	81-85	Before 61	61-65	66-70	71-75	76-80	81-85
Alfalfa					3			3			3							
mixed																		
irrigated					3			3			3							
rainfed																		
Cotton		2		1		2					1	2					1	
mixed																		
irrigated		2		1		2					1	2					1	
rainfed																		
Rice		3	1	2	2	1		3	3	2	2			4	2	4	4	1
mixed																		
irrigated		3	1	2	2	1		3	3	2	2			3	2	1	3	
rainfed														1		3	1	1
Barley			5	4	2			6	4	2								
mixed																		
irrigated			3	2	1			3	2	1								
rainfed			2	2	1			3	2	1								
Beans	10	7		13	7	3	23	9	2	8	2	5	4	2				2
mixed	6	1					16	2	1		1							
irrigated	2	3		10	6		2	4	1	4		3	1	1				2
rainfed	2	3		3	1	3	5	3		4	1	2	3	1				
Maize	8	2		13		14	38	3	1	16	8	3	12	1		6		4
mixed	8	2		13		5	21	1		4	1	2	12	1		6		3
irrigated						2	11	1		7	1							
rainfed						7	6	1	1	5	6	1						1
Sorghum				22	5	3				12	5	3						
mixed				22	2	3				12	5	3						
irrigated					3													
rainfed																		
Soybeans		2	1	4	10	4		1	3		2			1	1	2	2	1
mixed																		
irrigated		2	1	4	7			1	2		1			1				
rainfed					3	4			1		1				1	2	2	1
Wheat	36	10	10	9	12	16	38	2	8	13	1	5						
mixed	4	1	2	4	1	1	13	1	4	5		1						
irrigated	32	9	8	5	11	14	7		2	3		3						
rainfed						1	18	1	2	5	1	1						

Source: INIFAP, Listado de Variedades Liberadas por el INIA, 1942-1985, 1987.

North: States of Baja California Norte, Baja California Sur, Sonora, Sinaloa, Chihuahua, Coahuila, Durango, Nuevo Leon, Tamaulipas, and Zacatecas
Center: States of Aguascalientes, Jalisco, Nayarit, Michoacan, Guanajuato, Queretaro, Hidalgo, Mexico, Morelos, and Tlaxcala.
South: Other States.

Mixed: All materials suitable for both rainfed and irrigated production.

The regions called the Comarca Lagunera, and las Huastecas are included in the North; the Bajio, Mesa Central, the Sierra Tarasca, and the Oaxaca Mixteca are in the Center; the Tierra Caliente and Soconusco are in the South.

Figure 4. Crop cultivars released by
INIA, by production system, 1961-1985

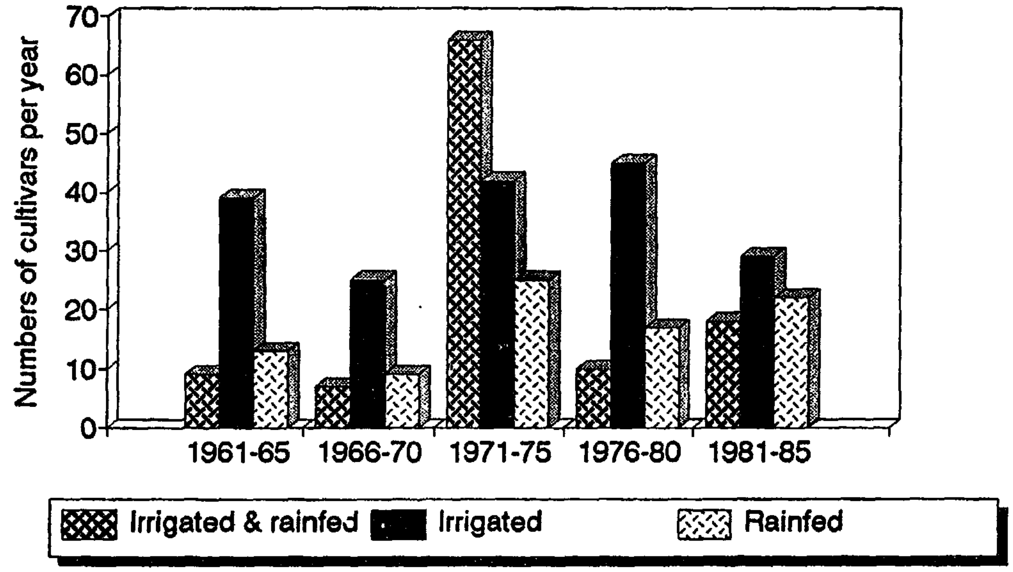
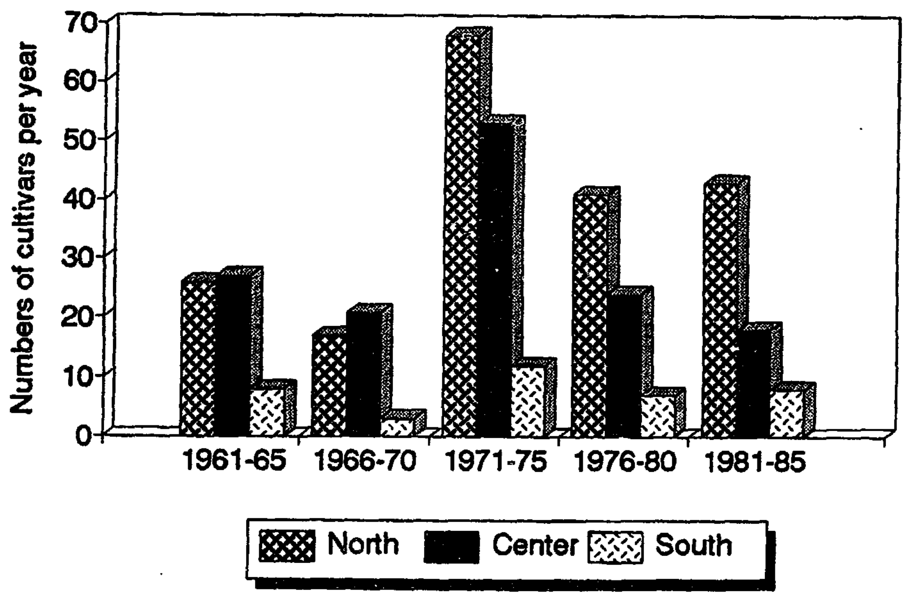


Figure 5. Crop cultivars released by
INIA, by region, 1961-1985



3.12 Livestock research after the creation of INIP. In 1967, INIP was formed and mandated to continue with the successful achievements of the FMD campaign. INIP and INIA shared pasture and forage research until the creation of INIFAP. INIA concentrated its pasture work in the selection, evaluation, and introduction of germplasm while INIP studied pasture utilization by animals. INIP remained small, having four experimental fields in 1970.

3.13 The structure of animal research in the 1970s and until the creation of INIFAP consisted of two broad areas, veterinary and animal production. Under the former were departments of bacteriology, vector control, epizootiology, physiopathology, hematoprotozoans, immunology, biological products, parasitology, and virology. Under the latter were aviculture, forages, genetics, pasture management, animal nutrition, and reproduction. The predominance of the medical fields, resulting from the initial structure of the institutions, continued.

3.14 During the 1970s, research objectives changed with the creation of 18 new sites, most in the tropics. Research in the areas of production, particularly cattle and forages, prodominated. Between 1970 and 1979, INIP ran 718 experiments with cattle, sheep, goats, swine, poultry, and horses; 50 percent of them were in cattle, 10 percent each in poultry and sheep, 8 percent in goats, 3 percent in swine, and 2 percent in horses. In pastures and forages, INIP reported 128 experiments, representing 17 percent of the total research effort. Most of the pasture and forage work was for tropical cattle feeding.

3.15 A review of 2,560 papers in the Mexican cattle production literature (1930 to 1983) showed the following distribution:

Table 3.3. Distribution of Experiments in Livestock Research, 1930-83

Animal Health	16.5%
Pastures and Forages	13.0%
Animal Nutrition	12.5%
Dairy Cattle	12.5%
Physiology and Reproduction	10.5%
Bovine, General	10.5%
Beef Fattening	9.5%
Animal Genetics	5.5%
Dual Purpose cattle	5.5%
Cow-calf Systems	4.0%
Total	100.0%

Source: Mission analysis of NIFAP data.

3.16 Animal health has received the most attention as a result of historical institutional arrangements. Genetic improvement ranked lower because feed shortages and poor seasonal feed distribution limited production more than animal production potential did.

IV. CURRENT RESEARCH PROGRAMS

4.01 INIFAP is the central component of the national agricultural research system. Because we lack information on the other components, this chapter and the following two concentrate on INIFAP, mentioning the others where possible.

A. INIFAP

4.02 In 1985, the federal government joined INIA, INIP, and INIF, creating INIFAP. INIFAP's mandate is to:

a. Execute the national crop, livestock, and forestry research programs.

b. Develop technologies to support programs of technical assistance and health in the forestry and livestock areas.

c. Study improvement, use, and conservation of soil and water for agricultural use.

d. Study input use for forestry and livestock production.

e. Validate technology in its appropriate socioeconomic and ecologic environment.

f. Diffuse results produced by the institute.

g. Provide training and scholarships for agricultural research.

h. Exchange technical information, research materials, and staff with national and international organizations.

i. In collaboration with agencies working in technical assistance, extend results produced by the institute.

4.03 Organization. INIFAP is organized on three levels: administrative, disciplinary, and commodity/thematic. At the administrative level (Figure 6), there is a general directorate in Mexico City, with three attached directorates--for training and information dissemination, research, and administration. Various subdirectorates report to them.

a. The next level is the CIFAPs, of which there are 34 (one for each state and one each in the Lagunera and the Panuco regions). The CIFAPs work directly with the state delegations of SARH and have limited autonomy in administrative and budgetary matters. The CIFAPs are responsible for the direct management of roughly 100 major experimental sites throughout Mexico.

b. At the disciplinary level, there are five CENIDs. These are basic research centers in microbiology (Federal District), macrobiology/parasitology (Morelos), agroclimate (Durango), physiology (Queretaro), and wood technology (Puebla). There is a related center for biotechnology research, which acts like a CENID, though it is not a part of INIFAP (Box 1).

c. At the commodity and thematic levels, there are research networks (redes de investigacion). Each network typically has a national coordinator and three regional coordinators, corresponding to the national organization of INIFAP. The networks have various themes (Table 4.1) by commodity, groups of commodities, research techniques, or problems; they coordinate work by topic or product to avoid duplication.

Table 4.1. INIFAP Research Networks

Agriculture	Livestock	Forestry	Integrated
Maize and Maize * Beans	Dairy Cows	Integrated Handling of Forestry Resources	Forage
Grains (Wheat, Rice, Barley, Oats)	Beef Cattle	Non-Timber-Yielding Species	Agrosystem Productivity
Sorghum and Millet	Sheep	Genetic and Planting Improvement	Land Use Systems
Edible Legumes	Poultry and Minor Species	Fires	Soil and Water Conservation
Oilseeds and Amaranth	Swine	Urban Wood Technology	Domestication of Potential Species
Vegetables	Epidemiology	Forestry Products Supply	Halophytes
Roots and Tubers	Apiculture	Firewood	Extension
Tropical Industrial Species (Coffee, Cocoa, Rubber, and Coconut)	Technology of Livestock Products		Phytopathology
Deciduous Fruits	Goats		Entomology
Tropical Fruits (Citrus, Mango, Zapote)	Work animals		Weeds
Fibers (Cotton and Henequen)			Mechanization
Ornamental Plants			Socioeconomics
Postharvest Handling			Technological Innovation
Seed Technology			Aquaculture
			Water-Soil-Plant-Atmosphere Relationship

Source: INIFAP.

4.04 Scientific staff. In 1990, INIFAP had approximately 1,800 scientific staff, with another 285 in training courses. Roughly 10 percent have doctorate or equivalent degree and another third have the MSc. The share of doctorates is low for a country of Mexico's income, but is similar to the share elsewhere in Mexico's agricultural research system.

4.05 Budget. Budget data for INIFAP and its predecessors is not available in detail after 1982. Table 5.2 reconstructs spending data for INIFAP, its predecessors, and other branches of the national research system. Spending in 1973 and in 1983 was typically less in proportion to the value of output than in countries of similar income, but it had risen from the 1960s. By 1989 relative spending had fallen drastically. With respect to countries with $1,000-$2,000 income per capita, Mexico's value of 0.36 percent of agricultural product was roughly one quarter of the levels of the others.

Box 1. Government Research Activities in Biotechnology

The federal government is undertaking substantial research in biotechnology, financed through the National Council of Science and Technology (SEP and CONACYT). There was a national expert group on biotechnology during the administration of President de la Madrid. Under the new administration, CONACYT has identified eight priority areas including biotechnology. Based on a $46 million budget in 1989 (including $10 million each for research and technology and $25 million for fellowships), it intends to allocate $1.4 million for biotechnology research, focused primarily on agricultural biotechnology, in addition to fellowships. Its goal is to double its budget in the near future, giving high priority to biotechnology and training.

There are five main public-sector institutions:

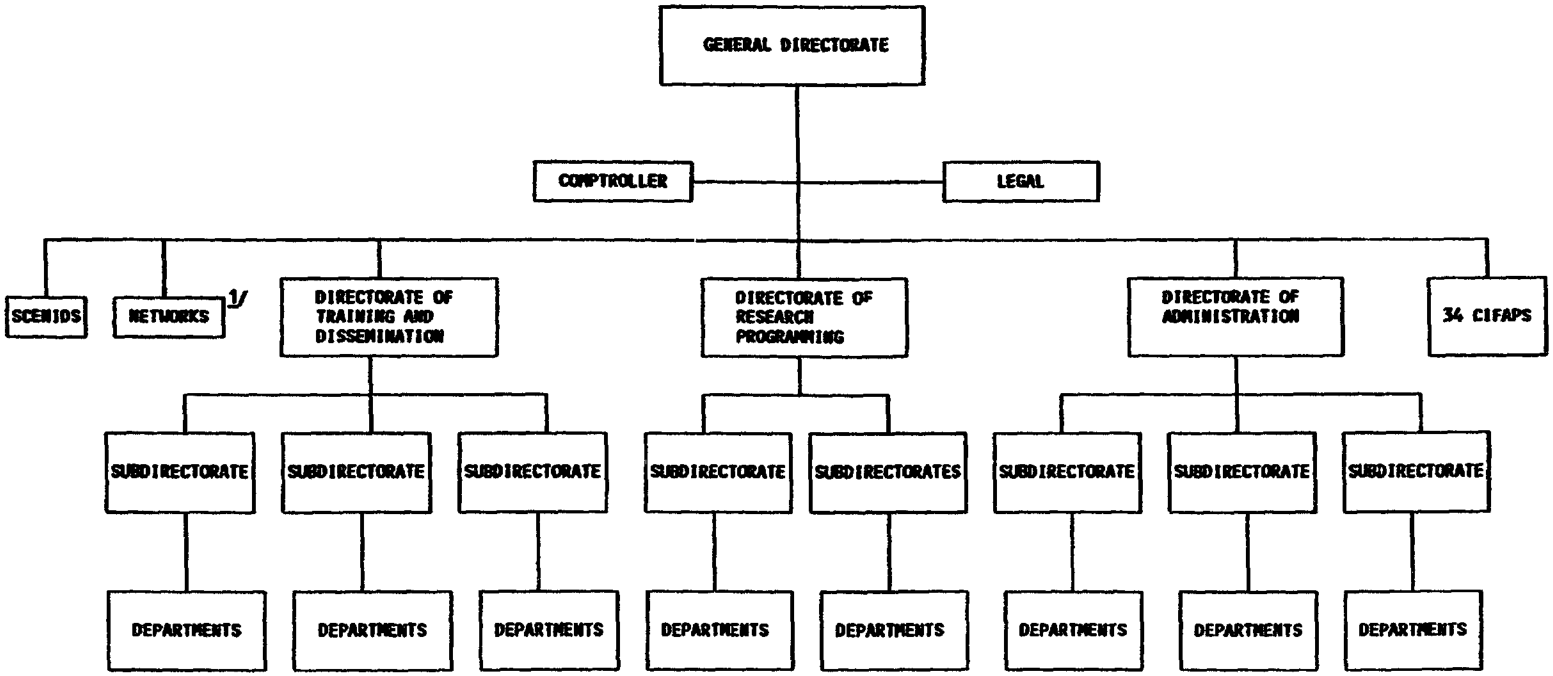
- *Centro de Investigacion y de Estudios Avanzados* (CINVESTAV) at Irapuato, Guanajuato, working on plant biotechnology,
- *Colegio de Postgraduados at Chapingo,* also working on plant and crop biotechnology,
- *Centro de Investigacion Cientifica de Yucatan* (CICY) at Merida, Yucatan, working on plant tissue culture,
- Center for Genetic Engineering and Biotechnology and Center for Nitrogen Fixation, both UNAM facilities in Cuernavaca, and
- A new center for animal biotechnology formed in December 1989 at the University of Nuevo Leon in Monterrey.

These are, however, only a few of the institutions involved.

The center at Irapuato is clearly a high-quality operation, based on scientists with world-level connections. In at least one area (restriction fragment length polymorphism--RFLP), the center is advanced enough to be transferring technology to CIMMYT. It receives high priority in salaries and funding. It supplements its CONACYT/SEP funding with research grants and contracts from the international scientific and development communities, as well as with private-sector agreements.

Advanced techniques have been used in several of the INIFAP breeding programs. Six INIFAP laboratories were using tissue culture in 1985, though three of the programs have been discontinued due to budgetary stringencies.

FIGURE 6. Organization Chart of INIFAP



1/ Functional Units (Not Structural)

Source: INIFAP.

B. Parastatal Enterprises

4.06 Parastatals were formerly very important in Mexico's agricultural research, providing research and extension, marketing, and production services. Recent government policy changes have greatly cut the : activities. Several--CONAFRUT (fruits), TABAMEX (tobacco), and CONADECA (cocoa)--were issolved. Others--AZUCAR (sugar) and INMECAFE (coffee)--have been reduced in scope; their remaining research activities are described in Chapter 7.

C. Other Branches of the National Agricultural Research System

4.07 A census by the Postgraduate College of Chapingo (CPCh) and the National Council of Science and Technology (CONACYT) in 1983-84 provides an overview of other Mexican agricultural research institutions, scientific training, and budgets, and permits a comparison with a similar census in 1973-74.

4.08 Institutions. In 1983-84, there were 70 institutions managing 4,092 research projects. Of the 70 institutions, 53 were academic, 8 were federal, 5 parastatal, 2 state, and 2 private. This count does not include subsidiaries of foreign firms importing results of foreign research into Mexico.

4.09 Staff. From 1973 to 1983, the national system--federal, state, academic, and private--grew rapidly in staff. The 70 institutions had 2,836 staff, of whom 11 percent had PhDs and 30 percent MScs. In 1973/74 there were only 1,067 staff. While the share of PhDs did not change from 1973/74 to 1983/84, the with Mscs rose to 859, up from 17.5 percent to 30.3 percent.

4.10 Budgets. Research expenditures grew respectably with respect to agricultural gross domestic product (GDP). Most growth was due to expansion of academic research programs, since the federal agricultural research budget apparently did not change between 1973 and 1983 as a share of system research spending.

4.11 The aggregate 1973 budget was Mex$0.916 billion, or 1.14 percent of agricultural GDP. Expenditures per staff in the national system fell from Mex$312 million in 1973 to Mex$194 million in 1983. At the same time, the share of recurrent costs rose. Since the principal component of recurrent costs is in fact salaries, one may conclude that the larger number of scientists after 1973 had fewer resources to work with by 1983.

D. International Agricultural Research Centers

4.12 The CGIAR centers are active in Mexico (Table 4.3). The principal form of collaboration is Mexico's participation in international breeding nurseries distributed by those centers. These centers work on the country's main food crops and production systems, but not on crops with export potential or in which private research is well-supported.

Table 4.2. CGIAR Research Centers Working in Mexico

Center	Crops	Activities[a]	Principal Environment	Scientific Staff in Mexico
CIMMYT	wheat maize	all all	irrigated northwest tropics	headquarters
CIP	potatoes, sweet potatoes	germplasm collection and exchange regional network[b]	central highlands	none
CIAT	beans	breeders' network		none
	tropical pastures, rice, cassava	breeders' network	humid tropics	none
ICRISAT	sorghum	breeding, agronomy agronomy	highlands and tropics	3
	chickpea	international nursery	irrigated northwest	none
IBPGR	genetic resources	germplasm activities	several	1
IRRI	rice	international nursery	irrigated northwest	none
ICARDA	lentils	international nursery	irrigated northwest	none

a/ Centers typically provide documentation and training services as well.
b/ The Regional Potato Cooperative Program (PRECODEPA) is the regional network. The International Potato Center (CIP) has included Mexican sites in collections of wild potatoes.

Source: Mission interviews.

V. BARRIERS TO TECHNOLOGY GENERATION AND TRANSFER

5.01 Mexican agricultural research has had many successes--but recent years have seen a weakening in the impact of research on agricultural growth. In this chapter, we explore the possible reasons.

5.02 A principal reason has obviously been inadequate budget for public agricultural research. Yet, there are other contributing factors. These include inefficient budgetary allocations; high research and extension costs imposed by variable environments; legal barriers to private research; inefficient technology transfer caused by an inadequate extension system; and the role of the seed industry as a main conduit for transmitting seed-based technology to farmers. Other barriers, specific to individual commodities, are analyzed in Chapter 6.

5.03 Specific hypotheses are:

a. That public spending on agricultural research is too low. This is analyzed by comparing Mexican spending to that of other countries.

b. That the research system does not choose its priorities correctly. The management of resources among different crops, environments, and techniques affects the return to research. Changes in these divisions might permit greater efficiency with a given investment.

c. That traditional commodity-based research techniques are unfit for the complexity of Mexico's agricultural environments. Diversity in production environments might dictate new diagnostic and analytic approaches for designing and extending technologies. Because such approaches would be so specific, they would also be more costly.

d. That private-sector contribution is too low. Mexico's income level is great enough to sustain some private investment in agricultural research and extension. Despite important successes in private research and extension, there are many areas without such initiatives; it is vital to understand the barriers to them. The focus here is on legal barriers (Chapter 7 notes technical problems with individual commodities).

e. That the extension service is inefficient. This service affects the speed and breadth with which innovations are transmitted to farmers--thus if extension is inefficient, the return to a given research investment is lower.

f. That seed policy and institutions have failed to further adequate diffusion of seed-based technologies. New seeds have been the source of gains in factor productivity, thus their availability to farmers is crucial. However, there are large areas with little or no use of improved cultivars produced by research. The seed sector might be implicated in that failure.

5.04 While some of the these issues can be dealt with in detail only in commodity case studies (as in chapter 7), the following sections present answers to some of the broader questions about the research system.

A. Insufficient Public Research Investment

5.05 Even when the contribution of universities and other entities is taken into account, Mexico invests less than countries of similar income levels. Its situation has worsened since the mid-1970s.

5.06 Estimates for the first 15 years of INIA show that Mexico spent less than regional averages for Latin America and for Asia. Estimates are available only for crops research, as good data were lacking for INIP or INIF. Even though relative spending had grown by 1974 (the last period shown in Table 5.1), Mexico spent less than 40 percent of the tropical Latin America average and less than one third of the temperate Latin America average.

Table 5.1. Agricultural Research Spending, as a Percentage of Agricultural GDP

	1959	1965	1971	1974	
Temperate South America	0.77	0.90	1.72	1.29	
Tropical South America	0.27	0.52	0.76	1.03	
Central America and Caribbean	0.23	0.26	0.42	0.71	
West Asia	0.48	0.50	0.72	0.83	
South Asia	0.16	0.21	0.30	0.31	
Southeast Asia	0.16	0.46	0.52	0.49	
East Asia	0.97	1.96	2.92	3.10	
	1960-64	1965-69	1971-73	1974-76	1983
Mexico					
National Institutes	0.13	0.09	0.21	0.41	0.60
National Institutes plus others	0.27	0.18	0.42	0.82	0.80

Source: Boyce and Evenson, National and International Agricultural Research and Extension Programs. Bank estimates for Mexico.

5.07 More recent budget estimates for INIFAP/INIA plus the contributions of the other branches of the national agricultural system do not alter this conclusion. Even adding the amounts spent by universities and other agencies would not raise the relative levels of Mexican spending to those of other countries in the region.

Table 5.2. Indicators of Agricultural Research Spending in Mexico
(1988 Mex$ millions)

	1973	1983	1989
INIFAP/INIA budget	81,309	232,667	130,000
Total budget (INIFAP/INIA plus all others)	389,851	504,592	215,225
Weight of research in activities outside INIFAP/INIA	30.0%	30.0%	30.0%
Weighted total budget	173,872	314,244	155,567
INIFAP/INIA research as a share of national research	40.7%	58.0%	49.3%
Value of agricultural output	29,152,222	39,060,500	43,333,377
Weighted total budget as a share of agricultural output	0.60%	0.80%	0.36%
INIFAP/INIA budget as a share of agricultural output	0.28%	0.60%	0.30%

Source: Mission analysis of INIFAP data.

B. Orientation of the Public Research Budget

5.08 The historical focus of INIFAP and of its predecessors was on wheat, maize, beans, and other staples, mainly with irrigation. A criticism of the predecessors was that the priorities were wrong. One goal of the 1985 reorganization was thus to change priorities among crops and production environments, making research more responsive to producers' needs.

5.09 Congruence analysis is a technique for studying research priorities. Congruence measures the fit between a planned allocation and a desirable one. Planned allocation can be defined by budgets, staff, or numbers of experiments; the desirable allocation can be measured by commodity production, the value of production, or other measures of production impact on consumers.

5.10 An index of congruence is the expression:

$$C = 1 - S_i[(p_i - d_i)^2],$$

where p_i is the planned allocation in unit i, d_i is the desirable allocation, the term $(p_i - d_i)^2$ is the squared deviation of planned from desirable, S is the summation operator, and C is the congruence index. Letting the measure of planned allocation be numbers of experiments, the unit be the state, and the measure of desirable allocation be crop area, then p_i is the number of experiments in state i divided by the national number of experiments, and d_i is the area in state i divided by the national area. A value of C equal to 1 indicates perfect congruence, implying that a research organization could gain little by shifting its priorities. A value of 0 indicates no congruence, implying that an organization can become more productive by shifting its resource allocations.

5.11 A legitimate criticism of congruence analysis is that market measures, such as the quantity or value of production, do not adequately reflect farmers' priorities, which may include timely food supply or reduced risks, among others. This criticism is not dealt with here. However, the issues of farmers' priorities and risky production, as major concerns of the research enterprise, are discussed in a subsequent section on variable environments.

5.12 Regional priorities. INIFAP has reported planned experiments for 1990-94 by state, network, and crop group. Those experiments were compared to crop area and the value of crop production in each state (Table 5.3). The congruence index is between 0.97 and 0.98, meaning that planned experiments are almost perfectly congruent with respect to the political divisions of the country.

5.13 While planned experiments were reported by network (Table 5.4), it was not possible to do congruence analysis of them because we did not know how experiments were assigned to networks. A limited analysis was done of experiments classed by major crop groups (Table 5.5). This was done by assigning experiments from the integrated networks, such as plant pathology and entomology, to the principal commodity studied. Basics--maize, beans, wheat, and rice--are the subject of about 45 percent of all planned commodity-specific experiments. This is smaller than their share of output and much smaller than their share of cropped area. Oilseeds are to receive 10 percent of commodity-specific experiments, livestock (including forages) 23 percent, and exportable goods 22 percent.

5.14 The incongruencies can be explained by INIFAP's tacit recognition of the roles of private and international research. Since wheat, maize, rice, and beans receive significant support from the international centers, it is reasonable that their allocations are smaller with respect to the value of output. The shares of livestock and forage experiments are very low compared to the value of production. As there is significant private livestock research among veterinary companies, it is correct that the government invest less. There appear to be too few experiments in tropical fruits and industrial crops, given that the private contributions to such research are small. While the shares of important exportables (horticulturals and temperate fruits) are small, private activities are important, so the overall balance is probably good. The experiment share of oilseeds is high, reflecting the government's preoccupation with slow growth in those crops, the rise in imports, and the failure to achieve sustained successes with imported technologies.

5.15 Irrigated and rainfed priorities. We know that historical allocations to rainfed sites were lower than those to irrigated ones. Because we have no data on the split between irrigated and rainfed experiments in the INIFAP portfolio, we cannot analyze exactly the current congruence of experiments with respect to irrigation. Taking experiments per state and analyzing them for congruence with rainfed crop area shows a very high congruence (Table 5.3).

5.16 This inefficiency can be resolved by shifting resources to rainfed sites. The shift can be justified on an allocative basis, in that complementary private resources are less available in the tropics. For example, there has been rapid growth of private vegetable research in the irrigated north and center of Mexico. While there are some private activities in the south (dairy and veterinary companies, horticultural producers' associations), their impact has been weaker than in the north.

Table 5.3. Congruence Analysis of INIFAP Experiments by State

State	Population: Total (Thousands)	Population: Density (#/km2)	Area Planted (Hectares)	Value of Output a/ (Million Mex$)	1990-94 Experiments (Numbers)
Aguascalientes	629	112.5	160,190	15,820	828
Baja California Norte	1,328	18.9	274,449	81,585	868
Baja California Sur	279	3.8	73,035	12,414	401
Campeche	583	11.2	136,554	9,067	4,581
Coahuila	1,086	7.2	221,058	51,480	1,290
Colima	398	73.0	156,599	36,370	383
Chiapas	2,392	32.4	1,076,096	229,046	1,440
Chihuahua	2,188	8.9	1,101,551	127,906	3,277
Distrito Federal	9,931	6,625.1	31,877	13,824	561
Durango	1,328	11.1	678,819	63,341	8,542
Guanajuato	3,389	110.8	1,271,874	168,147	3,734
Guerrero	2,423	38.0	728,063	88,103	1,051
Hidalgo	2,795	133.2	514,365	51,216	394
Jalisco	4,972	62.0	1,328,021	235,798	2,065
Mexico	10,176	474.2	856,918	162,584	5,264
Michoacan	3,233	54.0	1,030,960	163,502	2,948
Morelos	1,160	234.8	152,387	35,263	961
Nayarit	813	29.4	291,024	57,556	1,224
Nuevo Leon	2,969	46.0	260,846	13,382	723
Oaxaca	2,587	27.1	855,190	142,502	1,313
Puebla	3,850	113.5	969,967	116,222	1,127
Queretaro	862	73.3	199,970	20,806	203
Quintana Roo	330	6.6	211,906	5,112	666
San Luis Potosi	1,916	30.5	473,303	49,776	738
Sinaloa	2,198	37.8	1,408,231	238,448	2,526
Sonora	1,716	9.3	805,718	166,181	3,366
Tabasco	1,228	49.8	213,930	37,633	2,223
Tamaulipas	2,176	27.3	1,423,593	128,975	3,240
Tlaxcala	633	161.7	255,816	38,005	188
Veracruz	6,258	85.9	1,170,039	226,645	3,944
Yucatan	1,230	31.3	353,994	22,864	1,048
Zacatecas	1,226	16.3	1,292,725	91,998	1,933
Total	78,282	39.8	19,979,068	2,901,570	63,051

a/ 1985 value of output expressed in 1988 pesos.

Source: Mission analysis of SARH and INIFAP data.

Table 5.4. INIFAP Experiments by Network

		Planned experiments, 1990-94	
		Numbers	Shares
Agricultural Networks			
Maize and Maize Associations		6,435	10.2%
Small Grains		3,664	5.8%
Sorghum and Millet		1,478	2.3%
Grain Legumes		5,144	8.2%
Oilseeds		2,726	4.3%
Horticulturals		2,373	3.8%
Roots and Tubers		886	1.4%
Tropical Industrials		834	1.3%
Temperate Fruits		2,932	4.7%
Tropical Fruits		1,904	3.0%
Fibers		283	0.4%
Ornamentals		255	0.4%
Post-Harvest		465	0.7%
Seed Technology		1,114	1.8%
	Subtotal	30,493	48.4%
Livestock Networks			
Milk		1,251	2.0%
Beef		968	1.5%
Sheep		487	0.8%
Poultry and Minor Species		253	0.4%
Pigs		315	0.5%
Epidemiology		492	0.8%
Bees		39	0.1%
Animal Product Technology		46	0.1%
Goats		597	0.9%
Work Animals		5	0.0%
	Subtotal	4,453	7.1%
Forestry networks			
Forestry Management		1,429	2.3%
Non-Wood Species		753	1.2%
Forestry Improvement		2,029	3.2%
Fires		331	0.5%
Urban Wood		291	0.5%
Forest Products Storage		279	0.4%
Firewood		256	0.4%
	Subtotal	5,368	8.5%
Integrat networks			
Forages		3,545	5.6%
Agricultural Systems		3,225	5.1%
Land Use		1,219	1.9%
Soil and Water Conservation		1,551	2.5%
Domestication		204	0.3%
Halophytes		103	0.2%
Information Dissemination		995	1.6%
Plant Pathology		2,351	3.7%
Entomology		3,112	4.9%
Weeds		1,381	2.2%
Mechanization		182	0.3%
Socioeconomics		1,746	2.8%
Technical Innovation		484	0.8%
Aquaculture		20	0.0%
Water/soil/plant relations		2,619	4.2%
	Subtotal	22,737	36.1%
TOTAL		63,051	100.0%

Source: INIFAP.

Table 5.5. Composition of INIFAP Experiments by Group, 1985

	Experiments (numbers) 1990-94	Shares of total 1990-94
Commodity-Specific Experiments		
Staples	2,448	4.3%
Maize	9,840	17.2%
Beans	4,804	8.4%
Rice	1,461	2.5%
Wheat	2,026	3.5%
Oilseeds	4,629	8.1%
Subtotal	25,208	44.0%
General Livestock	200	0.3%
Meat	2,965	5.2%
Milk	1,673	2.9%
Eggs	38	0.1%
Forages	5,900	10.3%
Subtotal	10,776	18.8%
Exportables	10,047	17.5%
Nonspecific Experiments		
Resource Use Efficiency	5,648	9.8%
Others	5,696	9.9%
Subtotal	11,344	19.8%
Totals	57,375	100.0%

Note: Commodity-specific experiments are all except "resource use efficiency" and "others."

Source: INIFAP.

C. Variable Environments

5.17 Mexican agricultural policy long concentrated on irrigation. Public research followed irrigation by generating appropriate crop cultivars and associated agronomic techniques. Those efforts neglected the dry rainfed and tropical zones, but they did produce much of the growth in agriculture after World War II.

5.18 As it became more important to exploit the growth potential of the tropics and dry rainfed sites, a first step was to increase resources allocated to them, beginning in the 1970s. While previously it was possible to argue that the tropics were seriously underfunded relative to irrigated sites, some of the imbalance has been corrected.

5.19 The next step is to decide whether different research methods are needed for the tropical and rainfed environments. The argument in favor says that tropical/rainfed zones have three distinctly greater sources of variability. The most important source is agroclimate, mainly in the length and riskiness of the cropping season affecting the enterprise mix and the incidence of pests and diseases. A second source of variability is producer characteristics--notably less wealth, smaller farm size, and poorer education--that make adoption of new production methods slower, more costly, and ultimately less widespread. A third source is site-specific variations in soils, terrain, slope, and their interactions with agroclimate and producer characteristics. Site-specific variations are especially costly in terms of the scale on which new cultivars and methods can be used without costly local adaptive research. All these variations make it more expensive to transfer research from irrigated and temperate to rainfed and tropical areas.

5.20 Tropical agriculture requires a farming systems research (FSR) approach--this is today's near-conventional wisdom. An FSR approach to technology generation concentrates on

a. Problem diagnosis with on-farm methods so that scientists may understand traditional farming practices and incorporate them into new practices. On-farm research also provides more appropriate test environments for new practices under the biological and physical stresses typically faced by poor farmers.

b. Explicit consideration of interactions among activities on the farm. The complexity of low-income farming systems is a risk-reducing element that research programs must take as a constraint. For example, multiple enterprises are a characteristic of tropical and rainfed sites that justify FSR, as opposed to commodity research. Multiple enterprises are responses to variations in agroclimate, soils, and producer characteristics. It is often argued that they are more tractable with FSR than with a commodity approach.

c. Productivity gains from small modifications in production techniques. Because it is too risky to adopt major changes in the farming system, the FSR approach eschews radical technical changes.

5.21 What is the case for FSR in Mexico? There are many Mexican examples of commodities in which commodity research has not succeeded fully. The outstanding one is failure to achieve the kind of technology transfer in tropical and rainfed maizes that has been achieved with irrigated crops and with some other rainfed crops. Another instance is coffee, in which yields have barely improved, despite expanded area. A rainfed case is beans, where yields have remained low after decades of study. In those crops, and others like them, there is a wide gap between potential and actual yield caused by local variability as noted above. Reducing yield gaps is the most appropriate use of FSR techniques.

5.22 Where have FSR techniques contributed to technical change? Worldwide evidence from the tropics shows many successful commodity programs, suggesting that FSR techniques are not always conditions of technical change in such environments. Examples from Mexico are cocoa, tropical livestock with introduced forage grasses, henequen, and citrus. In none of those illustrations was FSR-type research a prerequisite for technical change, adoption, and growth; what usually occurred was expansion of new enterprises onto unused lands, with little research support.

5.23 There are limited examples of success with FSR in transferring existing techniques from other zones or from different sites within similar environments. These examples, almost without exception, involve transfer of proven cultivars or cropping techniques--not improvements in traditional techniques.

5.24 What elements of the FSR approach should be added to the commodity approach? An appropriate technology generation sequence has nothing fundamentally different from what has been successful with irrigation, but does require different emphasis at points in the sequence. The expanded tropical and rainfed research effort does not have to abandon the focus on specific commodities, as is sometimes contended. But effort needs to be expanded and appropriate FSR techniques incorporated.

5.25 The research sequence ought to be:

a. Where germplasm is unavailable from other zones (for example, tropical wheats and fruits), invest more in efforts to improve the germplasm base, since these crops can borrow less from temperate zones. The new research emphasis will take longer to produce results, because it involves new techniques (one is breeding for drought resistance) that cannot be borrowed immediately from irrigated or better rainfed areas. The FSR approach is not directly relevant at this step.

b. In crops grown in diverse environments (particularly maize, beans, and sorghum), continue to adapt successful germplasm from temperate sites.

(i) Increase resources for crop adaptation to local stresses, especially drought and pests. Crop adaptation has better short-term prospects because it can exploit a base of existing technologies. The FSR approach is important for defining desirable characteristics of cultivars to test in farmers' conditions.

(ii) Identify the causes of adoption failures of that germplasm using yield-gap methodologies--a component of FSR. Yield-gap methods partition the difference between experimental and farm crop yields into such factors as soil quality, pest incidence, input use, and risk aversion; they are an essential tool in adapting technologies to new environments. The commodity studies show that the entire national program--INIFAP plus the other branches--is weak in this type of research, principal tool FSR can add to the Mexican national program.

c. Capture local variability in production conditions by increasing the numbers of sites and treatments. While this is partly a restatement that greater resources are essential, it implies a need for more diagnostic research in agroclimate and its interactions with genetic materials and farmer characteristics.

d. Concentrate on improving the output of individual commodities. Markets for land, labor, and capital exist throughout Mexico and provide diversification for farmers beyond what they can achieve on their own farms. Research is not obliged to treat multiple enterprises as imposed by farmers' needs to diversify.

D. Legal Barriers to Private Agricultural Research

5.26 The legal structure is a vital part of technology generation and transfer. Laws protect the rights to benefits from innovations, thereby providing incentives to create and market new products; if innovators' legal rights are frail, research will not be done at all or must be done by the public sector. If protection of innovators' rights grows, then new private projects will develop and some public sector activities will gradually move to the private sector. Defining the strength of legal protection is essential, therefore, for recommendations about privatization of research. Expanded research will not take place unless legal issues on distribution of benefits can be resolved.

5.27 There are three basic legal issues affecting research and extension: laws on intellectual property and trade secrets, those on technology transfer, and those on private financing of research and extension.[1] Laws of intellectual property influence incentives for new products--such as higher-yielding plant varieties. Laws of technology transfer influence imports of technology--for example, hybrid vegetable cultivars grown by Mexican firms under license to foreign companies. Laws affecting private financing refer to the fiscal incentives for investment--such as the tax deductibility of research expenditures.

Intellectual Property Issues

5.28 The regular patent system. Under the patent law of 1987, the following are not patentable:

a. Plant species, animal species, and biological processes for obtaining them;

b. Foods and drinks for human consumption and processes to obtain or to modify them;

c. Biotechnology processes to obtain pharmaceuticals, medicines, feed for animal use, fertilizers, pesticides, herbicides, fungicides, or products with biological activity;

d. Genetic processes to obtain plant or animal species or their varieties thereof;

e. Chemical products;

f. Pharmaceuticals, medicines, feed for animal use, fertilizers, pesticides, herbicides, fungicides, or those products with biological activity.

5.29 A new patent law becomes effective in 1997, when it will be possible to patent pharmaceuticals, animal feeds, and so on, as well as the processes to obtain them. It will still not be possible to patent plant or animal species, biological processes for obtaining them, or food or drink for human consumption. It will be legal to patent genetic methods for obtaining new species. A process using a genetically modified microorganism will be patentable if used to obtain a nonfood product but not a food product.

5.30 Both before and after 1997, the patent law has a compulsory licensing provision if the patent is not used in Mexico within three years of issue. Before 1997, a certificate of invention is available for procedures to obtain foods and drinks and for biotechnology processes. Such a certificate is subject to compulsory licensing at a royalty.

5.31 Plant variety protection. Mexico does not have a PVP system and apparently does not plan to develop one, though the Secretariat of Commerce and Industrial Development (SECOFI) is reviewing intellectual property issues including PVP. The wisdom of adopting a system depends on the extent to which it would actually encourage local plant breeding and the import of proprietary varieties. Even without PVP, many proprietary cultivars are sold in Mexico, from both domestic and foreign sources. While most cultivars are hybrids whose inbred breeding lines are protected biologically, there are also many varieties. Firms producing and selling varieties rely on continued

[1] The seed law is reviewed in a subsequent section on seed policy.

seed quality to establish client relations and thus to protect themselves from predatory competition against which they have no legal defense.

5.32 Trade secrecy law. Legal arrangements to protect trade secrets or "know-how" are crucial to all research, so that legitimate owners may proceed effectively against someone acquiring the secrets by stealing them. There is criminal law prohibiting the revelation of secrets (Codigo Penal para el Distrito Federal, Arts. 210 & 211), but the technology protection issue does not appear to have been discussed yet in practice. Mexico is among the countries most frequently cited by U.S. firms reporting trade secret inadequacies or remedy and enforcement ones. The available laws, therefore, do not appear to be well enforced.

Technology Transfer

5.33 Under a 1972 law, substantially amended in 1982, SECOFI reviews and registers technology transfer from abroad. The law forbids registration of contracts having specific objectionable clauses--for example, those prohibiting export of products of technology, if the technology is already within the nation, or establishing too high a price.

5.34 The amended 1990 "Transfer of Technology Regulations," to be discussed in the next section, provide much greater freedom to transfer trade secrets into the nation. These regulations do not provide legal support for lawsuits against firms that have obtained trade secrets illegitimately. The issue is likely to be considered with changes in the patent law.

5.35 New regulations of January 9, 1990 weakened the 1982 law. These regulations specify more permissive interpretations of objectionable clauses. They then use a general exception provision in the law to permit registration of any agreement bringing various benefits within three years of registration, including permanent employment; improvement of the technical quality of human resources; access to foreign markets; fabrication of new products in Mexico, especially if they substitute for imports; improvement of the balance of payments; decrease of unit production costs; development of national suppliers; use of technologies that do not contribute to ecological deterioration; and initiation or strengthening of research and development within productive units or national research centers tied to them.

5.36 Biosafety. Biosafety refers to possibly harmful effects of new biological methods on the environment or on the genetic composition of scientific materials. Although there is no indication of public unease, scientific concern is leading to organization of a biosafety review panel. The issue was faced on an ad hoc basis when the private sector proposed a test of transgenic tomatoes in the winter of 1988-89. To develop a more systematic procedure SARH has organized a committee and has consulted with USDA. According to the private sector, however, this panel does not yet have precise rules or procedures to offer firms considering tests of genetically engineered organisms. Private firms are unlikely to proceed with investments in Mexico until the panel's review standards are more sharply defined. As with the pesticide regulatory process, this process requires more transparency and more specific guidelines.

5.37 Certain scientific issues merit study in this connection; under some circumstances, the risks of release of genetically modified organisms may be different in Mexico then elsewhere. (For example, some important plants such as maize have wild relatives in Mexico but not in developed nations those cultivars.) The risk of transfer of a novel gene into wild relatives through hybridization must thus be considered in Mexico, and will probably not have been considered in any developed nation in which the novel gene has been tested.

Taxation of Research Expenditures

5.38 There is no limit on deducting actual expenditures for research and development. Under general law, a 1981 program allows deductions for payments into funds for technological investigation. These payments are tax-deductible only up to one percent of a firm's gross income and must be placed in an irrevocable trust (Ley del Impuesto Sobre la Renta, Art. 27). Although larger deductions are possible upon approval by CONACYT, the percentage limit is a barrier to those long-term cooperative research programs that would rely on such funds. Finally, under a decree of August 11, 1987, there are tax credits, ranging from 15 to 30 percent for research expenditures, and exemptions from import duties.

5.39 Other legal barriers to agricultural research. There appear to be essentially no other direct obstacles to research, save for work with transgenic organisms. While it was sometimes difficult in the past to obtain permits for field testing with new or imported cultivars, it is not hard today, although there are apparently no clear standards. No particular difficulties in importing reagents, equipment, or materials seem apparent.

Conclusions

5.40 Plant variety protection and trade secret law. There is no patent protection for plant or animal varieties in Mexico, but some protection is provided by trade secrecy law. Domestic and international firms use this law to protect inbred lines in hybrid crops, strains of microorganisms in production, and laboratory procedures. Trade secret protection is regarded as inadequate both by foreign business and by at least one Mexican legal authority. The ambiguous area between plant variety protection and trade secret law requires clarification with respect to its effect on competition--but it does not appear to impede the introduction of new genetic materials into private agricultural research and extension, with the possible exception of single-cross hybrids. This is because many materials can be hybridized (maize, sorghum, and vegetables) and others can be economically protected by quality control and marketing efforts.

5.41 General patent law. Several serious ambiguities remain in the general patent law. First, the 1997 changes in the categories of protectable products are equivocal about processes that can be used for producing both food and non-food products. Second, implications of the delay to 1997 in changing the patent law are doubtful. Biotechnology inventions are unlikely to be on the market before then, although new pesticides might be. For products available in the next seven years, there may be perverse incentives to delay innovation and publication during the period just before 1997. Unless there are special transition arrangements in the law, firms may be concerned about marketing products in Mexico that are patented abroad before 1997 and arguably not patentable in Mexico after 1997 (because they have been used abroad and are no longer novel).

5.42 A third related problem is the legal unknowns outside Mexico. There are practical problems of knowing what foreign patents have been granted and of deciding when to invest in foreign patents. For example, will U.S. or European import laws exclude agricultural products derived from genetic materials patented in these areas but not in Mexico? As is true of patent law for all product groups, Mexico needs better information on foreign patent issues affecting its exports.

5.43 The principal recommendation is to clarify the legal ambiguities, especially those due to the 1997 change in the patent law, its coverage of protectable products, and its effect on the timing of innovations. While SECOFI is reconsidering the entire patent issue, including proposals to accelerate transition to 1991 and to broaden the patent laws, remaining obscurities may constitute barriers to biotechnological and genetic research with long lead times. This reconsideration should involve an explicit analysis of PVP.

5.44 Technology transfer. The law on technology transfer now appears quite permissive. More importantly--whatever the legal status of such transfers--imported technology has had a powerful impact on the historical growth of Mexican agriculture. Imported inputs (machines, seeds, fertilizers, pesticides) and techniques to use them have all been transmitted rapidly from abroad since World War II. Hence, while it is important to clarify and enforce technology transfer laws, especially as related to PVP and to general patent law, legal issues on technology transfer have not been decisive in causing the slowdown of growth.

5.45 Taxation of research expenditures. Tax deductibility of research expenditures is complete, but in practice this has little effect on private research because there are so few national firms doing it. More important is the limit--one percent of gross sales--on the deductibility of contributions to funds for research. As such funds, called patronatos, are the most important type of private financing to agricultural research, the limit is a barrier to their enhancement. While case-by-case exemptions are possible, it would be simpler to raise the limit. Given the need to duplicate the patronato model outside the main one of Sonora state, this is an important reform.

E. Extension

5.46 The extension service is the principal means of transferring new technology to Mexican farmers. It has five principal branches: SARH, the agricultural trust funds, the parastatals, input suppliers, and private firms (Table 5.6). We know very little about the last two and they are not discussed in detail.

Table 5.6. Extension Service Structure

Institution	Technical Staff	Client Group	Activities	Research Links	Cost-Sharing
SARH	8,320	all farmers	mainly crops and livestock	through demonstration plots and INIFAP publications	10-20% in irrigated districts; very low elsewhere
FIRA	1,890	low-income and other farmers	crops, livestock, agro-industries, aquaculture	through FIRA demonstration fields	recently begun with some progress
FICART	510	ejidos	as FIRA		
INMECAFE/IMPA	230	coffee, sugar	research and extension integrated	nil in coffee; positive but unknown in sugar	
Input suppliers	mainly field demonstrations		input use		complete via price
Commercial banks	3,327				

Source: Mission interviews.

5.47 The SARH extension service. SARH has about 60 percent of the total extension staff of the federal government, the agricultural credit banks, INMECAFE, and IMPA. It provides basic technical assistance in agriculture and livestock, with emphasis on basic food crops. Research links are maintained by contacts with INIFAP but are weaker with academic research centers, other than the Post-Graduate College centers in the tropics.

5.48 The agricultural trust funds. FIRA (the Bank of Mexico's Agricultural Trust Fund) and the Trust Fund for Rainfed and Irrigated Areas (FICART) are the principal agricultural trust funds. FIRA provides technical assistance through its own agents (775), those (3,327) of the commercial banks to which it re-lends, and those (1,111) in a special program for low-income producers. FIRA helps with productive activities, training, and farmers organizations. FIRA organizes demonstrations of crop and livestock technologies in collaboration with INIFAP, private seed companies, and farmers. Producers have access to several sources of information via FIRA, and research links appear good.

5.49 FICART has loan appraisers/extension workers with the same training as those of FIRA or of SARH giving technical assistance in crops, cattle production, agroindustry, fisheries, fruit production, other animals, and agroindustries. While FICART has no demonstration centers or plots run by cooperating farmers, its borrowers have access to demonstrations run by SARH or FIRA, so research links are similar.

5.50 Parastatals. INMECAFE has an extension program with 30 technical staff. Assistance is limited to coffee growers, with good research links as INMECAFE does research as well (see Chapter 7). There is no cost-sharing. IMPA has a larger program with strong ties to IMPA research and to the sugar mills. Other parastatals--notably CONAFRUT and TABAMEX--have been disbanded.

5.51 The efficiency issues in extension are analogous to those in research. Does the extension service have adequate resources to fulfill its mandate? Does it allocate resources appropriately to regions and production systems? Is it correctly balanced with the parastatals and private firms providing technical assistance?

Previous Bank review of extension

5.52 In 1984 the World Bank reviewed Mexico's extension service, evaluating mainly the SARH, with some attention to parastatals such as INMECAFE, CONAFRUT, and TABAMEX. It identified problems related to amounts and management of resources devoted to extension.

5.53 Resource problems identified in 1984. Extension staff were poorly paid, with no clear career path and severe operational budget constraints.

5.54 Nonresource problems identified in 1984. The review described two broad classes of problems: structural ones affecting institutional coordination, planning, and data collection; and operational ones affecting staff incentives, coordination among SARH units, relations with farmers organizations, research-extension linkages, and credit.

5.55 Specific criticisms were made of the following areas:

a. Administration. Strict separation of responsibilities between irrigated and rainfed districts for extension made it difficult to exchange information between systems. Overlapping authority among extension staff, other parts of SARH, and the parastatals led to the same farmer being visited by several people.

b. Farmer participation did not receive high priority in work planning.

c. Methodologies. There was no clear national methodology.

d. Training had inadequate priority.

e. Extension/research linkages were poor.

f. Role of extensionist. Extension workers were asked to do many unrelated jobs, including data collection, credit monitoring, and input distribution.

5.56 Implemented reforms. In 1985, SARH began major reforms in extension. These were:

a. To unify irrigation districts (DR) and rainfed districts (DT) as rural development districts (DDR);

b. To delegate budgetary responsibility to the DDRs;

c. To create a generalist extension worker position as the main farmer contact, and to provide specialized technical advice from the districts;

d. To relieve the extension worker of extraneous responsibilities by creating information units in the districts;

e. To give extension work a sharper socioeconomic focus;

f. To improve linkages to research, partly by reinforcing district technical committees to define research priorities;

g. To improve staff training.

5.57 Other reforms were then pending, including better incentives for staff, more use of private consultants, and greater cost-sharing. An attempt has been made to implement them in PROCATI, a project that began in 1987.

Evaluation of Reforms

5.58 The various proposed reforms appear in summary in Table 5.7. Criticisms of the extension service are strong, if that is defined only as provided by SARH. If the definition is expanded, however, to include technical assistance delivered by the "other agencies"--trust funds, parastatals, input suppliers--the those criticisms are weaker. On the major issues of staff numbers and of cost-sharing, other agencies make significant contributions.

Table 5.7. Extension Service Reforms

Aspect	Before 1984	Reforms in 1984/85	PROCATI Component	Current
Organization	irrigated districts (DR) and rainfed districts (DT)	rural development districts (RDD)	RDD	RDD
Budget authority	districts for DR, state for DT	RDD	RDD	RDD
Extensionists responsibility	technical assistance planning data collection	technical assistance only	technical assistance only	little change from pre-1984
Specialized support to extensionists	absent	to be given by districts	given by districts	available in some districts, but not all
Research linkages	thought weak	to be reinforced	special program of on-farm validation trials	several special programs including Bank supported PROCATI and PRODERITH
Private extension and cost-sharing	limited to irrigated areas and cash crops; some through credit system	cost-sharing in	goal of 50% northern districts	
Staff incentives and operating budget	--------Agreed to be inadequate----		special incentive payments given	
Staff training	--------Agreed to be inadequate----		field and specialized courses	

Source: Mission interviews.

5.59 Resource problems. In 1984, there were thought to be about 21,400 technical assistance staff in SARH, plus other public agencies and parastatals. This has fallen to roughly 14,300 by 1990, with SARH and "other agency" staff numbers both dropping by about one third. Cuts in SARH extension staff have not been restored by adding staff to other agencies.

5.60 Two ways of relieving these resource scarcities without spending more are to change staff placement and to improve cost-sharing. The congruence indices for numbers of extension staff with area by state and with value of crop production by state were greater than 0.95; the indices for extension workers ranked as "good" with area and with value were also greater than 0.95. Therefore, numbers and qualities of extension workers are allocated proportionately to planted area and to the total value of crop production.

5.61 Though we lack data on extension workers by district and so cannot analyze congruence by the value of production by irrigated and rainfed districts, we can do so by state. While the index was 0.96 (showing that the fit at the state level was good), that result is somewhat misleading because rainfed districts had more staff than irrigated districts. The 1985 value of rainfed output was about 52 percent of the national total, while rainfed districts had 74 percent of staff. This misallocation is justified by the fact that farmers in irrigated districts had better access to private extension, but it does show that there is little to be gained by shifting public extension staff to the rainfed and tropical districts unless total numbers of staff are restored to those prevailing in 1984/85.

5.62 A second way is to complement public investment in extension by shifting some costs to the private sector, as has been urged strongly in previous Bank reports. Cost-sharing in SARH and the remaining parastatals is now minimal, with the only well-established source being the irrigation district water charges. Cost-sharing is complete in the private input suppliers, well advanced in FIRA, and less so in FICART. Cost-sharing with low income producers is a recent (1985) innovation in FIRA. It now recovers nearly 40 percent of all costs of technical assistance from low-income producers, and has a goal of 100 percent. FICART's goal is to recover only 30 percent of salary costs, but the current level is probably close to zero.

5.63 Administration. Irrigation districts and rainfed districts combined to become rural development districts, but the irrigated districts have now been put back under the supervision of CNA. Hence, the previous review's criticisms stand.

5.64 Farmer participation and methodologies. The critique of extension was that it failed to use farmers' knowledge, via farming systems research, and that it insisted on commodity-oriented work when a diversified approach could give better results.

5.65 The use of training and visit methodologies (T&V) in PROCATI is well-established at the district level, and serves as a model for other districts. It will also be used by the rural development project (RDP) now under appraisal. T&V is not used, as such, by the other agencies, and in their work farmer participation is less robust.

5.66 Extension/research linkages. One critique of the research/extension linkage was that crops, livestock, and forestry research were in three subdirectorates of SARH. This critique has less validity now. With the creation of INIFAP, there is a central agency for crops, livestock, and forestry, with explicit administrative links to extension. There are also formal mechanisms between SARH and other agencies to coordinate research/extension linkages (these include the technical committees of PROCATI and of PRODERITH, INIFAP input into the agricultural credit banks, collaborative field demonstrations by INIFAP and SARH, and INIFAP plus SARH collaboration with PRONASE).

5.67 Examples of effective linkages abound. INIFAP produces many extension publications for farmers and for technical staff. A 1990 study of maize extension workers revealed that those documents were the main source of current information to extension staff. INIFAP scientists give training courses for extensionists. INIFAP livestock production modules (participation by CPCh and the Mexican Institute of Water Technology (IMTA) are in wide use. Field supervision of PROCATI, and of the rural financial subsector, demonstrated that extensionists had good knowledge of INIFAP staff and results.

5.68 Linkages are strong in technical assistance from the input suppliers because they have a natural interest in providing advice about the use of products. Linkages are also good in the parastatals, because of their history of providing integrated research, marketing, and technical assistance in one crop.

5.69 Role of extensionists. A 1990 study of maize extensionists analyzed their time allocation. Results from Guanajuato state showed average shares of time per job to be: technical assistance, 48 percent of total; statistics, 18 percent; work plans and reporting, 14 percent; administration, 20 percent. Results from other states are similar, so the criticism made in the 1984 review stands. The combined share of statistics, work plans, and reporting is nearly one-third of the total, thus reducing it to 20 percent would add more than 10 percent to the aggregate staff time available for technical assistance.

F. Seed Production and Marketing

5.70 Mexico has a 40-year history of state intervention in the seed industry; the main aim has been to establish a reliable supply of quality seed. The government implements seed policy through PRONASE, which has generally held 30-40 percent of the certified seed market and is supported partly by a restrictive seed law and by subsidies. This policy has come under increasing criticism. As the driving force for technical change in agriculture will be genetic progress, principally in seeds, it is important to answer questions about seed policy and how it affects incentives for seed production, seed marketing, and technical change.

The Seed Law

5.71 The Seed Law of 1960 (Ley 22-XII-1960) was the basis of policy. Its key feature was that only PRONASE could distribute INIFAP cultivars:

> Article 8. – Original seeds of plant varieties improved or developed by the Institute [INIFAP and formerly INIA] must be delivered to PRONASE for inclusion in commercial seed production. The supply of seeds to entities or individuals will be done through PRONASE with prior agreement of the Minister of Agriculture and Hydraulic Resources.

5.72 Except for "seed useful for planting" (semilla apta para sembrar)--material distributed illegally or semiofficially in time of shortage--all seed must be of varieties approved by the Plant Varieties Qualification Committee (CCVP) and entered in the National Plant Varieties Register (RNVP). Under Article 12 of the Seed Law, the CCVP includes representatives of the Agricultural Economics division of SARH, the Plant Protection Service, INIFAP, SECOFI, CONAFRUT, PRONASE, and the private sector. The actual testing is done by INIFAP with overall coordination by SNICS.

5.73 The 1983 changes to the 1960 Act had significant impact on the industry.

a. The National Seed Production, Certification and Marketing System was enlarged to include "private sector enterprises officially recognized by the Secretariat of Agriculture and Water Resources as engaged in seed research, multiplication, and marketing" (Chapter II; Art. 5; V).

b. PRONASE was given explicit preference to receive and use INIFAP varieties (Chapter III; Art. 6).

c. All seed from INIFAP that could be used for seed production by organizations and individuals would now be controlled by PRONASE (Chapter III; Art. 8).

d. The CCVP was enlarged to include the National Commission for Distribution of Basic Foods (CONASUPO), seed producing enterprises, and agricultural training institutions, through accredited representatives (Chapter IV: Art. 12).

e. PRONASE was to receive preference from agricultural lending institutions and from state enterprises selling other inputs (Chapter V; Art. 27).

5.74 A 1991 revision of the Seed Law lifted the restriction of distribution of INIFAP germplasm; INIFAP is now free to distribute its germplasm to anyone. The same Law further allows private plant breeding, and requires SARH approval only for work with high-risk transgenic organisms. Both are significant reforms which should create greater competition in the generation of seed-based technologies. The 1991 Seed Law allows greater flexibility in the seed certification and registration procedures, and allows private firms to certify seed. It also defines a new category (semilla verificada) in which the user of the seed verifies that the seed meets the standards set by the government.

PRONASE

5.75 The 1960 Seed Law created PRONASE from its predecessor, the National Maize Commission (CNM). The Seed Law controlled what entities could produce basic, registered and certified seed and set an official price for seed. PRONASE had, until end 1989, a secured market for nearly 40 percent of its output through the National Bank for Agriculture Credit (BANRURAL), paid no business earnings tax, received a substantial subsidy, and had a near-exclusive right to cultivars developed by INIFAP, as specified by the Seed Law.

5.76 With sales rising from 5,000 mt in 1960 to 215,000 mt in 1982, PRONASE held between 35 and 61 percent of the certified seed market in Mexico from 1975 to 1986 (Table 5.8). Excluding 1982, the average was 117,000 mt from 1975 to 1985. Wheat provided about half of sales from 1975 to 1986, rice, maize, beans, and soybeans another 45 percent. Sorghum, forages, fruits, and vegetables have been unimportant in PRONASE's portfolio but do make up much of seed imports and of the sales of private companies. PRONASE's production capacity has typically been greater than its annual production or sales. The most recent estimate of rated capacity is 193,000 mt of all seeds. PRONASE has had relatively high inventories; from 1985 to 1989, even after a period of selling off assets, they were between 41 percent and 63 percent of sales.

5.77 PRONASE's current operations. PRONASE has been profitable recently, though the profit margin declined from 32 percent in 1985 to 9 percent through the first eleven months of 1989 (Table 5.9 and Annex 2). Part of the decline in profits was due to a change in administrative expenses in 1988 and 1989. In 1985 and 1986 PRONASE reduced its work force roughly 10 percent each year to lower administrative expenses. Beginning in 1988 staff formerly on SARH's payroll but working for PRONASE--about 5 percent of staff--were formally transferred, thus raising salary costs and cutting the operating margin.

5.78 A second negative factor affecting the company's profits is increasing reliance on commercial bank borrowings due to cuts in the federal subsidy. Between 1985 and 1989 the federal subsidy decli..ed from 14 percent of total inflows to 9 percent; in real terms the 1989 payment was about one-fourth that of 1985. Interest expenses contributed to the large drop in other income between 1987 and 1988, and to the expected net loss expected in 1989. A third contributing factor was the decline in real prices of basic grains, which were close to 90 percent of PRONASE sales in the past five years. Between 1985 and 1988 the real value of sales fell by 12.5 percent per year, and income was approximately halved each year (Table 5.9).

Table 5.8. Production of Certified Seed for Major Crops, 1970-86
(000s mt)

Crops	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Maize	17.1	11.8	13.1	11.0	27.3	35.7	22.2	30.3	19.8	16.7	21.6
Pronase	17.1	9.9	8.7	6.5	24.0	32.6	17.1	26.4	13.8	8.4	13.0
Wheat	60.2	72.4	100.8	86.0	125.7	154.7	199.9	121.3	98.8	94.8	80.7
Pronase	60.2	39.5	46.3	43.3	50.6	84.0	126.4	59.2	74.8	58.9	39.6
Rice	5.5	4.9	4.3	13.5	17.0	21.8	21.8	22.3	13.8	24.8	11.4
Pronase	5.5	4.6	3.3	10.6	9.7	18.5	17.9	17.8	12.5	22.0	10.2
Beans	9.9	1.0	3.4	5.1	29.3	36.2	32.1	18.2	11.7	5.8	15.8
Pronase	9.9	1.0	3.3	4.8	28.9	35.1	31.5	16.5	10.7	5.4	14.6
Cotton	0.6	14.3	14.1	14.8	16.2	15.0	4.0	8.6	7.5	4.8	1.3
Pronase	0.6	1.3	1.8	1.1	1.9	0.9	0.3	1.4	1.8	1.5	0.0
Soybeans	6.1	26.0	29.4	37.7	29.3	32.1	28.6	29.0	23.9	38.6	29.0
Pronase	6.1	6.5	10.6	7.4	13.5	9.7	11.9	9.6	9.5	17.8	7.7
Sorghum	0.5	15.7	28.6	23.0	16.0	21.7	18.7	23.8	37.3	42.4	52.1
Pronase	0.5	0.2	1.1	1.9	0.9	1.6	1.1	2.6	2.3	0.2	1.4
Barley	1.3	11.7	24.3	26.5	32.2	33.6	9.3	15.8	28.9	37.9	24.1
Pronase	1.3	0.2	0.1	0.3	0.6	0.1	0.8	0.7	0.6	1.7	1.5
Alfalfa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pronase	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Totals	NA	165.0	235.3	232.8	302.6	363.8	352.3	278.3	252.0	275.0	240.6
Pronase	103.0	64.7	82.1	80.6	133.4	187.7	215.5	139.5	133.3	124.2	90.8
Other	NA	100.2	153.2	152.2	169.2	176.1	136.8	138.7	118.7	150.8	149.8

Source: PRONASE.

Table 5.9. Summary of Statement of Activity of PRONASE
(Millions of Mex$)

	1985	1986	1987	1988	1989 a/
Sales	13571	23783	43330	84870	92756
Cost of Sales	7862	14916	24039	44384	52424
Gross Profit	5809	0867	19291	40486	40332
Administrative Expenses	2095	4747	13995	33355	30500
Income from Operations	3113	4120	5296	7131	9832
Other Income	1750	1209	1249	367	(1839)
Total Income	4864	5329	6545	7498	7993
Gross Margin b/	42%	37%	45%	48%	43%
Operating Margin c/	23%	17%	27%	8%	21%
Total Margin d/	32%	21%	15%	9%	9%

a/ Through November 1989
b/ Gross Profit % Sales
c/ Income Operations % Sales
d/ Total Income % (Sales & Other Income)

Source: PRONASE.

5.79 A further damaging change will be the end of the favored partnership between BANRURAL and PRONASE. In the past, BANRURAL customers received PRONASE seed as part of their technology package, and in 1988 the bank represented about 40 percent of total sales. Under the new rural credit policy BANRURAL borrowers are no longer obliged to buy PRONASE but can buy on the open market.

INIFAP

5.80 INIFAP has three major roles in seed production: to develop plant varieties and hybrids through research, using genetic material from various sources; to release germplasm (original or breeder's seed) for increase; to test materials on its research stations for the CCVP. These trials are used to verify the performance of varieties inscribed by firms or individuals.

National Seed Inspection and Certification

5.81 The 1960 Seed Act organized SNICS, the official certification and inspection agency of the SARH, to regulate seed production, seed conditioning, movement of seed, inspection and tagging of different grades of seed, and maintenance of registers of seed producers and inscribed varieties. Under the 1991 Seed Law, SARH now carries out the functions of SNICS.

5.82 In this area, SARH

a. Maintains registers of seed producers, area planted for seed, industrial concerns engaged in seed processing, and all domestic and foreign seed transactions;

b. Verifies compliance with regulations on processing and storing of seed;

c. Certifies that the origin and quality of all seed is correct and appropriate for farmer use;

d. Issues and monitors the certificates of origin and quality, and issue labels for seed produced and processed;

e. Inspects production fields and processing plants;

f. Samples seed quality and vigor at all steps in the growing, processing, and storage phases; and

g. Serves on the CCVP.

5.83 Most of the SARH facilities are adequate to meet the quality control requirements of the Seed Act, but much equipment is old and needs to be replaced or upgraded. In particular, germination procedures are slowed for lack of growth chambers. This is critical at harvest time, when samples are taken to determine the germination of farmers' seed to calculate payments or to discard seed.

CCVP

5.84 This Committee rules on new varieties (including imports) to be placed in the RNVP. Members of the CCVP are from SARH, private seed producers, private seed users, and scientific institutions.

Private Seed Producers

5.85 The Mexican seed industry is well established and now controls 60-70 percent of the national market. Commercial production began in the mid-1940s; today there are about 40 companies in the industry. Eight are joint ventures with American companies (Pioneer, DeKalb, Asgrow, Funks, Northrup-King, WAC, Warner, Moran), more than 20 companies are wholly-owned by Mexicans, and the others are affiliated with foreign firms. Seven seed firms in Mexico have officially recognized research programs, of which three are wholly Mexican owned.

5.86 Private companies in Mexico are primarily concerned with crops that can be hybridized, such as maize and sorghum. This is because pure breeding lines are protected, and the purchaser has to buy new seed each year. More effort is now going into oilseeds (rapeseed, soya, safflower, sunflower), cotton, and some horticulturals; less is done on the small grains (wheat, barley, oats, or rice), which cannot be hybridized. Most work has been with irrigation or in areas of dependable rainfall.

5.87 American and Mexican companies typically conduct observation research. In 1972, DeKalb was the first American firm to receive permission to conduct varietal and seed research, and it has conducted a full range of research for maize, and on grain and forage sorghum hybrids. Several other companies, notably Pioneer, Asgrow, and Northrup-King, have worked on the same crops and have research permits. Varieties developed elsewhere, largely in the USA and Latin America, are tested in screening trials throughout Mexico, and promising materials are submitted to SNICS for inscription trials.

5.88 Social sector seed producers. The social sector comprises all seed producers outside PRONASE and the organized private sector, as defined above. It includes the Ejidos and smallholders who produce seed under individual contracts.

5.89 The largest group is the "seed producer associations", which can be formed into various semilegal legal entities and include ejidatarios, small growers and large farmers. Several ejidos produce seed under contract directly to PRONASE and for member use. Others produce seed under contract to private companies. Patronatos may qualify as "social sector" producers, but in most cases are more prosperous individuals or organizations.

5.90 AMSAC. The Mexican Seed Trade Association (AMSAC) represents the private sector. It includes all private firms, many seed producers associations, and some "social" organizations. AMSAC has tried for years to organize the private sector as an effective lobby, but appears to have had little influence on important policy issues. For example, it has representation on the CCVP, but with only one vote of the nine.

International Organizations

5.91 Mexico's research and seed production systems rely on the IARCs for some basic germplasm used in plant breeding (Box 1). The principal centers involved in moving germplasm through Mexico are CIMMYT and ICRISAT. For example, INIFAP relies on CIMMYT for most of its wheat germplasm, and uses CIMMYT maizes to develop its own germplasm. One focus of this review, therefore, was to determine whether there were barriers to movement and use of germplasm. CIMMYT has agreements with the Mexican government governing the use and distribution of germplasm to entities other than INIFAP. CIMMYT is prohibited from distributing germplasm directly to public or private companies or individuals within Mexico; all germplasm goes first to INIFAP, which decides on further release. CIMMYT notifies INIFAP of germplasm request from outside Mexico, but INIFAP has no right to prohibit export. The 1991 Seed Law allows free import of breeding materials for research purposes subject only to fitosanitary regulations.

5.92 ICRISAT follows much the same procedures as CIMMYT, with at least one extra step: all imported sorghum seed must first be grown in isolation at the CIMMYT tropical research station at Poza Rica. This is a quarantine measure against the accidental introduction of Asian plant diseases. ICRISAT releases sorghum and millets as CIMMYT does wheat and maize.

5.93 While the international centers would like to be freed from the obligation of passing all germplasm through INIFAP for release into the Mexican research system, SARH/CIMMYT regulations appear to have little effect on the distribution of CIMMYT germplasm in Mexico or internationally. In fact, private seed companies have been using CIMMYT maize germplasm for nearly 20 years to develop hybrids within Mexico and CIMMYT once held field days for private seed companies during which they would identify materials they would use for their breeding programs. These materials were exported to the U.S. and ultimately reimported into Mexico by Mexican counterpart companies for inclusion in their breeding programs.

Conclusions

5.94 In 1985-86, the Bank criticized government policy in the areas of market regulation, institutions, and scientific policy.

a. Market regulation and the role of PRONASE: It was suggested that (i) government regulation be limited to quality control, especially by removing unnecessary seed import restrictions; (ii) seed prices reflect supply and demand; and (iii) PRONASE be financially viable, with removal of government subsidies.

b. Institutions: that (i) a national seed council be established; and (ii) SNICS be strengthened to carry out its functions effectively.

c. Scientific policy: that (i) INIFAP materials be made available to the private and international sectors; and (ii) responsibility for producing foundation from breeder's seed be transferred to INIFAP from PRONASE.

5.95 Some progress has been made on those recommendations since 1986.

a. Market regulation and the role of PRONASE: (i) very limited government regulation still applies to varietal development and registration; (ii) Mexico has no official seed prices, so that private firms' prices do reflect supply and demand; (iii) Subsidies to PRONASE have been eliminated.

b. Scientific policy: Responsibility for producing foundation seed from breeder's seed is with INIFAP.

5.96 Current recommendations are:

a. Market regulation and the role of PRONASE:

i. PRONASE should continue promoting the formation of seed producers associations and assisting in strengthening their technical capacities, including more involvement with ejidos.

ii. PRONASE must divest itself of inviable facilities and operations. Sales of facilities and equipment must be done without restrictions on the buyer. Facilities should be upgraded by new investments or by shifting old equipment among production sites.

b. Institutions:

i. SNICS should become an independent agency of the federal government. If it cannot be removed from the SARH, it should have budgetary autonomy. At the very least, SNICS must separate itself from seed producers, especially PRONASE, to maintain the integrity of the inspection system.

ii. Field and quality control staffing must grow. Salaries must be raised to attract new staff and to keep experienced staff.

iii. All CCVP trial data should be made available to the organizations or individuals entering materials for inscription. These data would include the statistical analysis, to be published within one year of the trial.

c. Scientific policy:

i. INIFAP now can make breeder's seed available to all for breeding or for seed production. INIFAP should charge a fee for the production costs, as well as a users fee that would help to fund additional research. While it is improbable that all crop research costs can be recovered solely from the sale of breeder's seed, this might be a source of some incremental revenue.

ii. INIFAP researchers now lack the resources to undertake such increases and would require both investment and training to do this work. This is being done as part of a Bank-supported agricultural technology project.

iii. INIFAP should remove any restrictions on international centers releasing germplasm to individuals or organizations in Mexico.

iv. The new Seed Law allows marketing of national or foreign materials under some simple conditions of labelling for purity, appropriate use, disease and pest resistance, seed treatment, and germination. This is a positive step.

Box 2. Genetic Resources in Mexico

Since seed-based technology is and will be the main source of yield growth in Mexican agriculture, maintaining sources of genetic diversity for breeding programs is vital. The country has good access to world collections for materials at various stages of the breeding process and has exploited those materials very successfully in the past. But its capacity to collect, catalog, store, and use the full range of such materials domestically is limited.

Germplasm exchanges. Mexico has imported collections with great positive impact on its plant breeding programs. In a 1983 report on the genetic resources program, Mexico had received samples of 31 different species from 17 different countries in 1979 and 1980 alone. There is no difficulty in bringing materials from the U.S., with the exception of patented varieties and hybrids. Mexico participates in the Latin American Maize Project, which exchanges materials among the U.S., Mexico, and 10 other Latin American countries, in addition to the international research networks of such centers of IRRI, CIMMYT, ICRISAT, CIP, and CIAT. These exchanges are subject to the usual plant quarantine restrictions, especially for sorghums and maizes of African origin, but there appear to be no restrictions which hamper scientific access to useful breeding materials. Mexico also exports materials from its own collections. The 1983 report noted that Mexico had sent samples from at least 20 different species to 20 different countries.

National collections. Collections maintained in Mexico are shown in Box Table 1. There is a small program in INIFAP that collects native materials, receives foreign materials, catalogues them, and provides them to national breeders. Collections maintained in Mexico are shown in Box Table 1. The national network, based at Chapingo, has 7 staff, with 2 at Chapingo, 1 at Iguala, 1 in the Bajio, 2 in Zapopan, and 1 in Zacatecas. The University of Nuevo Leon does germplasm conservation and distribution for INIFAP in the northeast of Mexico.

The INIFAP program is too small to do much collecting, though collections proposed in collaboration are with CIP and IBPGR. There have been collections of maize, beans, and squash, beginning in the 1940s, as well as those of other important native species, notably chilies and avocado.

Priorities for expansion of genetic resources work are in conservation (all crops), in increasing diversity in oilseeds (especially sunflower, safflower, sesame, and rapeseed), perennials, tropical fruits, and tree crops, and in characterizing materials in the current collections.

IBPGR in Mexico. The International Board for Plant Genetic Resources (IBPGR) is part of the CGIAR. Its office at CIMMYT was created in 1988 and has one full-time representative, who is responsible for Mexico, Central America, and the Caribbean. IBPGR has assisted INIFAP in germplasm collection (*Capsicum, Lycopersicum, and Cucurbita*), multiplication technology (*Phaseolus coccineus*), foreign germplasm introduction (sunflower), seed conservation, and training. In 1988, IBPGR undertook collections of cucurbits and of some species of *Phaseolus, Gossypium, and Zea Mays* in Mexico and Central America. IBPGR has also helped the National University of Mexico, the University of Nuevo Leon, and other Mexican institutions in aspects of genetic resources.

Box 2 Table. Germplasm Collections in Mexico

Crop	Approximate Number of Materials
Alfalfa	unknown
Avocado	250
Barley	CIMMYT
Beans	8,000
Cassava	198
Chilies	3,000
Citrus	unknown
Cocoa	unknown
Coffee	1,000
Cotton	200
Cucurbits	400
Forage legumes	1,500
Gourd	300
Grasses	100
Henequen	15
Leucaena	unknown
Maize	10,000
Mango	unknown
Onion	10
Papaya	unknown
Plantain	unknown
Rice	unknown
Sesame	10
Solanum	80
Sorghum	1,500
Soybean	unknown
Sugar cane	1,778
Sweet potato	35
Vanilla	unknown
Wheat	CIMMYT

Source: INIFAP, Logros y aportaciones de la investigacion agricola en recursos geneticos (1983); Mission interviews with IBPGR and INIFAP.

VI. COMMODITY ANALYSES

A. Grains

1. Maize

6.01 Maize is the most important staple food of the Mexican people; about 66 percent of the crop goes for human consumption, thus roughly 120 kilograms per person per year. It is also the most important crop in terms of area, with 40 percent of cropland.

6.02 Mexico is within the center of origin of maize (Zea mays) and has the highest levels of maize genetic diversity in the world. Maize is grown in all 33 states and in all major agroclimatic zones by all types of farmers, from commercial to subsistence.

6.03 The country has been a large importer of maize for 15 years and has imported an annual average of 3 million tons in the last 5 years. Mexico's own yields have been stagnant since 1982, and the area sown to maize is declining slightly. Significantly this decline has occurred in the better sites, such as the more productive rainfed areas of the Altiplano (where it has been replaced by wheat), and in the irrigated Bajio (replaced by sorghum). Consumption is growing and Mexican maize requirements are projected by the year 2000 to be 21.1 million tons, with 12.5 million tons going to food.

6.04 Area. Irrigated maize is grown on about 400,000 hectares in the northern states of Tamaulipas, Chihuahua, Sonora, and Sinaloa; the remaining crop area roughly 6.6 million hectares, is rainfed. Rainfed maize is grown throughout the republic but is concentrated in the center and southeast. Seventy percent of rainfed maize is produced in six states, and the states of Jalisco, Mexico, and Chiapas account for 50 percent of rainfed production. The total area sown to maize over the last 25 years has declined some, with wide oscillations around an average of 7 million hectares.

6.05 Yields. The evolution of maize yields (1961-87) is presented in Figure 7 and shows three distinct phases. The first phase up to 1976 was one of slow growth (1.2 percent per year), a continuation of the pattern of previous decades. The second phase (1976-82) was one of rapid growth (6.7 percent per year). Inputs and credit were heavily subsidized and growth resulted mainly from greater use of inputs, especially fertilizer. The third phase (1982-87) shows little or no growth in yields. The average national yield over the past few years (1985-89) has hovered around 1,850 kgs/ha.

6.06 Regions and problems. The most prominent characteristics of maize-growing regions are given in Table 6.1, along with distinguishing regional features. Each region is designated by a number, which also appears on the accompanying map (Figure 8). The area of maize cultivated in each region should be considered as best estimates.

Figure 7. Mexico--maize yields (mt/ha)

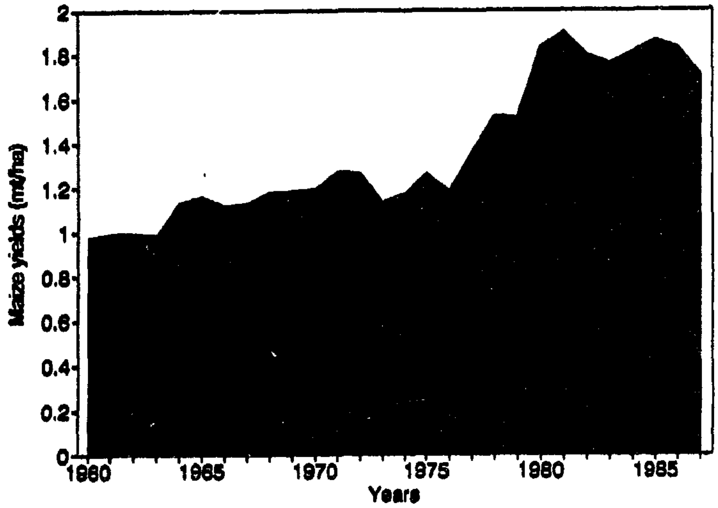
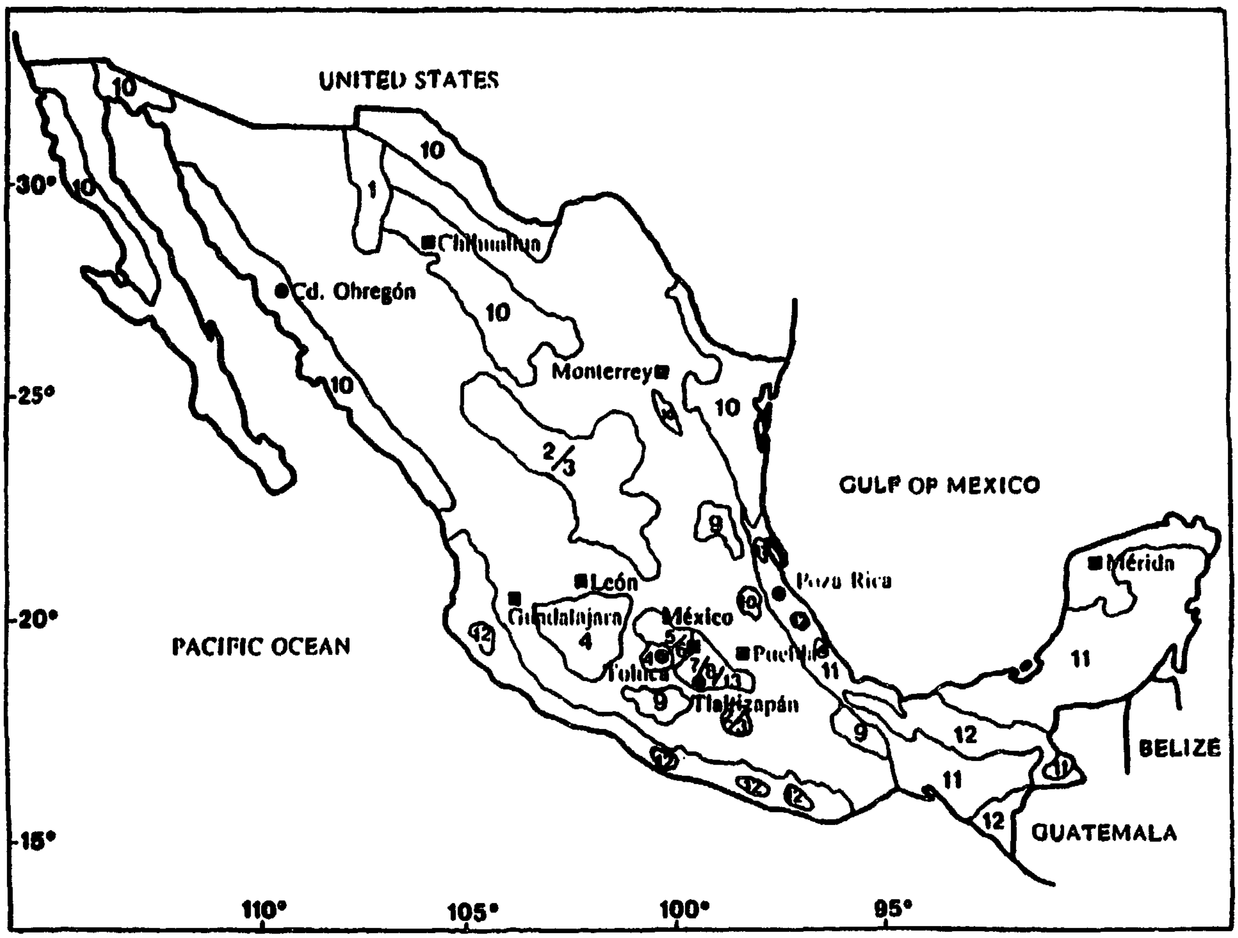


Figure 8. Distribution of Maize in Mexico and Classified According to Agroecological Zones



SOURCE: CIMMYT

Table 6.1. Maize Production Problems in Mexico by Agroecological Region

	REGION												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Area ('000 ha)	240	920	80	400	900	200	60	40	1000	400	2000	800	50
Ecology	HT	HT	HT	HT	HT	HT	HT	HT	ST	ST	LT	LT	TZ
Grain Type	WDWF	WDWF	YD	WDWF	WDWF	WDWF	WO	YF	WD	WD	WD	WD	WDF
Growing season	MA	MA	MA	MA	MA	MA	MA	MA	MA	MA	MA	MA	MA
Maturity	XE	E	L	IL	EI	L	EI	E	IL	IL	IL	IL	XL
Moisture	D	D	BC	AB	BC	BC	B	BC	AB	A	AB	A	A
Stalk rot	2	2	3	2	3	3	2	3	3	2	2	2	2
Ear rot	2	2	2	2	2	2	3	2	2	2	2	2	2
Stunt	0	1	0	0	1	1	0	0	1	2	3	2	1
Virus	1	1	1	2	2	2	1	1	2	3	2	1	1
Smut	2	2	1	2	2	2	2	1	2	2	1	0	0
Blight	2	2	2	1	2	2	0	1	3	1	2	1	3
Rust	2	2	2	1	2	2	0	2	2	1	1	2	2
Mildew	0	0	0	0	0	0	0	0	2	2	2	1	0
Tarspot	0	0	4	0	0	0	0	0	0	0	0	0	0
Fall armyworm	0	1	0	0	0	0	0	0	3	3	3	3	2
Borers	0	1	1	1	0	0	0	0	2	3	2	2	1
Soil insects	1	1	2	2	2	2	2	2	3	3	2	2	1
Earworm	1	1	2	1	1	1	3	2	2	2	1	1	1

The abbreviations used in Table 6.1 are as follows:

For Ecology:
- HT:Highland Tropics
- ST:Subtropical
- LT:Lowland Tropics
- TZ:Transitional Zone

For Growing Season:
- MA:Major Season

For Grain Type:
- WD:White Dent
- WF:White Flint
- WDF:White (Dent or Flint)
- YD:Yellow Dent
- YF:Yellow Flint
- WO:White Floury

For Maturity:
- XE:Extra Early
- E:Early
- I:Intermediate
- L:Late
- XL:Extra Late

For Moisture:
- A:Rarely Stressed
- B:Sometimes Stressed
- C:Frequently Stressed
- D:Usually under some Stress

For Disease and Insects:
The relative importance of the problem, as an average over 10 years or so, across the region is rated on a 0-5 scale.
- 0:Not present
- 1:Present but of no economic importance.
- 2:Some economic losses.
- 3:Significant losses.
- 4:Severe losses.
- 5:Maize cannot be grown unless a resistant variety is grown or chemical control is needed.

Source: CIMMYT.

6.07 From an ecological viewpoint, 40 percent of Mexico's maize is classified as highland tropical, 40 percent as lowland tropical, and 20 percent as subtropical (Table 6.1). The predominant grain type is White Dent with sizeable areas of White Flint in the highlands. Except for irrigated areas in the north, all of Mexico's maize is sown during the summer rainy season. Most maize is planted with the first rain after a 6-8 month dry season. As regards maturity, intermediate-to-late materials are required for the tropical and subtropical areas. A much broader maturities range is needed in the highland areas, where moisture and frost are more important. In terms of moisture, the tropical and subtropical areas have few limitations with some areas showing occasional stress, but in the highland areas, moisture stress is more the norm. The exception is an area of 400,000 ha located in the Toluca Valley and parts of Jalisco, Guanajuato, and Michoacan. There are large areas in the highlands that suffer severe moisture stress. Although soils are not considered a major limiting factor to maize production in Table 6.1, there are large areas of phosphorus-fixing soils in Michoacan, and soil acidity has been reported as limiting yield in Chiapas. A wide range of diseases attack maize wherever it is grown. In the highlands the most important diseases are stalk rot, ear rot, smut, and soil insects. In the tropics, fall armyworm, soil insects, stalk rot, ear rot, and stunt are the most important.

History of Research

6.08 Maize research has not seen the same spectacular success as the other Mexican cereal programs wheat, sorghum, and rice--but nonetheless it has played a significant role in raising maize production over 40 years. At the same time, it has faced many obstacles outside its control--such as seed production--that have hampered its effectiveness.

6.09 Although the Office of Special Studies never got more than 10 percent of the main maize area planted to its own improved seed, it soon became clear that maize is self-improving. The improved varieties released to farmers upgraded the *criollo* or native varieties through random interhybridization of the improved varieties with the local types. This led to farmers developing a series of varieties, most better suited to local conditions than those that were introduced. The low-yielding old varieties gradually disappeared; these included the poorly rooted *Conico* types once dominant in the high plateau, the *Conico Norteno* types prevalent in the Bajio, and the *Tabloncillo* varieties of Jalisco. This was a major contributing factor to the expansion of area grown to maize and to the resulting growth in production in the 1950s and 1960s.

6.10 Hybrids cover all the irrigated areas in Tamaulipas, Sonora, Sinaloa, and the Bajio. Some of these come from the multinational private sector. While these companies have had research programs in Mexico for the development of inbreds and hybrids, much seed for the hybrids sown is imported, based on inbred lines developed elsewhere. Last year, an estimated 4,000 tons of seed were imported for this purpose.

6.11 Over the years INIA and INIFAP have released many hybrids but these have had very little impact because their area has been so limited. Even today, no more than 15 percent of the maize area is sown with improved seed. This lack of adoption is generally attributed to poor seed production, both in quantity and quality, and is seen as a bottleneck blocking the effectiveness of research. The skills for hybrid seed production exist in Mexico but are not used very effectively.

6.12 Concurrently with its maize improvement program, the Office of Special Studies launched an aggressive program in soil fertility with emphasis in the central highland area. The results from this program became the basis for wider use of fertilizer, thus the large production gains of the 1970s. While Mexico's agronomic research in maize did not receive the same priority as breeding research, the recent effort of the National High Technology Maize Program (PRONAMAT) and associated work have tried to redress this.

Current Research

6.13 INIFAP's maize research is carried out within the context of the national maize network (red nacional de maiz), established in 1987. This network was initiated to provide a framework in which INIFAP's maize breeders could work more efficiently, avoid duplications and omissions, and have greater access to each other's germplasm and a wider range of testing sites. The national network leader is based in Chapingo. The network is divided into three regions: south, center, and north, each of which has a coordinator. Research priorities are set within each region based on regional and local priorities. Breeding locations spread throughout the country carry out a wide range of breeding activities.

6.14 Typical of breeding work done nationwide is that of the southern region of the network. This covers the states of Veracruz, Morelos, Oaxaca, Guerrero, Chiapas, Tabasco, Campeche, Yucatan, and Quintana Roo, including most of the rainfed subtropical and lowland tropical areas (Regions 9,11,12, Figure 8). The program is based on four breeding strategies: recurrent selection, hybridization, synthesis, gene pools (PABG). The program also has special projects in: drought resistance, by selecting for flowering synchrony; disease resistance, especially stunt and leaf blight; tortilla-making quality (*calidad nixtamalera*); and genetic resources.

6.15 Once INIFAP has selected the promising varieties or hybrids, these are sent to the CCVP, which decides, based on their uniform trials, on official release of the material. Each material has to have been in these trials for at least two years before release. Once released the inbred lines or varieties are given to PRONASE for hybrid production and multiplication.

6.16 Agronomic research in maize is very fragmented and does not have a strategic focus. Good work is being done in some areas, but this seems more the exception than the rule. Other than the work at La Frayleses, Chiapas, there is little diagnostic agronomic research underway at the moment. Much effort goes into validation programs, such as PRONAMAT, which are drawing on the results of past research by recommending "production packages". However, many agronomic problems still need to be researched.

Outlook and Conclusions

6.17 Lack of continuity in the breeding strategies of the national program has hindered progress over the years. Any successful breeding program needs a well-defined, long-term strategy, since results cannot be achieved in the short run. Lack of continuity in Mexico has revolved around the hybrid versus open pollinated variety (OPV) debate. The country needs programs on both hybrids and OPVs to cover all socioeconomic and agroecological conditions.

6.18 Mexican maize research faces many challenges and will into the future. For this reason it is most important that a dynamic research program should respond immediately to present problems and should have a strategic focus to solve long-term ones. That said, one must emphasize that probably no other crop in Mexico's agriculture has such a potential for increased productivity—and research will play a key role in this.

6.19 First, there is the urgent need to close the present production gap, drawing on knowledge that already exists and setting priorities and strategies for research to maintain production.

6.20 Breeding. For breeding, INIFAP divides the maize-producing areas into different "environments" based on productivity levels. These environments group the different regions outlined in Table 6.1. Breeding strategies are developed around these as follows:

a. Environment A: This covers roughly one million ha of irrigated land that has a yield potential of at least four tons/ha. This agriculture is highly commercialized with high levels of inputs, mechanization, and so on. Single cross hybrids would be developed for this environment, which at present is supplied hybrids mostly by the private sector.

b. Environment B: This is an area of 1.5 million ha that has a very favorable rainfall regime (>800mm) with deep soils and with a yield potential of over three tons/ha. It is mostly located in the Altiplano covering the states of Mexico, Guanajuato, and Jalisco. Single and double-cross hybrids would be developed for this area with the same characteristics as those for Environment A. At the moment, most of this area is sown to criollo varieties that in most cases have interhybridized with improved germplasm that has been released over the past 45 years. INIFAP has released hybrids for these areas but the adoption rate has been very low.

c. Environment C: This area covers approximately two million ha with rainfall of 600-800 mm annually and with a potential yield of three tons/ha. The area is almost exclusively situated in the semitropics and lowland tropics with the usual limitations of soil erosion, low fertility, and weeds. This area is also sown to criollo varieties and the rate of adoption of improved germplasm is very low. With proper crop management, however, good yields can be obtained. Double-cross hybrids would be developed for this area. Synthetics would also be developed for the farmers who could not afford to buy hybrid seed every year.

d. Environment D: This is the largest single area and occupies three million ha with an erratic rainfall regime of less than 600 mm, shallow soils, and drought stress almost every year. Yield potential ranges from 1.0 ton to 2.5 tons/ha. This area is mostly found in the highlands in the center and center-north and in the states of Yucatan, Campeche, Quintana Roo, and Tabasco in the south. Criollo varieties are grown in these areas and there has been very little adoption of improved germplasm up to now. OPVs would be developed for this environment with the emphasis on earliness to avoid drought stress.

6.21 Seed production and germplasm availability. There has been very little adoption of improved germplasm from the national program--although that adoption has played a major role in the "self-improvement" of maize through random interhybridization. The use of improved seed in any one year has never been greater than 15-20 percent at the national level. This is illustrated by data from PRONASE, which handles the seed production of all INIFAP varieties (Table 6.2).

Table 6.2. Area Sown to Seed from PRONASE in the Humid Tropics and Nationally (Average 1983-85) (hectares)

Region	Area (hectares)	%
Humid Tropics	194,133	8.7
National	382,626	5.2

Source: PRONASE.

Although hybrids have been released for many years by INIFAP and its predecessors, these have had little impact on production. The reasons given are that promotion of hybrids by the national seed producing company has been inadequate and that both the quantity and the quality of seed have been too low.

6.22 The private seed sector, largely multinational, has also not shown aggressiveness in moving into the high-yielding rainfed areas of the highland and tropics; it has been active only in irrigated areas. Multinationals' research programs are limited and very often they import hybrid seed produced from inbred lines developed elsewhere.

6.23 INIFAP may not have the resources necessary to compete with the private sector to develop hybrids, especially in the more favored areas, but it would have an important role as a producer of inbred lines, which could then be sold to private seed companies. Incentives, especially regulatory, should be provided to the private sector to increase their research effort for the irrigated areas, for the production of higher-yielding single-cross hybrids, and for research on hybrids for the more favored rainfed areas.

6.24 INIFAP will continue to play a key role in the development of synthetics and OPVs for areas that do not interest the private sector. Important areas cover three million ha of almost totally subsistence farming.

6.25 In the long term INIFAP has an important part to play in the exploitation of new sources of germplasm. Only a very small portion of the germplasm found within Mexico has been exploited in its breeding programs. There are 25 described races of maize in the country and many--such as Chapalote, Coniteco, Harinoso de Ocho, Pepitilla, Zapalote Chico and Bolita--have been ignored in the past. The heterotic patterns of these native races need to be explored.

6.26 Since the mid-1980s, CIMMYT has started a pure line development program. It is now offering inbred lines, along with the traditional improved populations, to national programs (including Mexico) capable of using them in hybridization. CIMMYT's move into hybridization will give a boost to Mexican scientists moving in this direction.

6.27 Crop management. Although much needs to be done in breeding, crop management will require even more research. There is no maize-growing environment where such research cannot raise productivity.

6.28 Research in crop management or agronomy is both limited and highly fragmented. It is uncoordinated with the activities of the national maize network and thus does not have any strategic focus. Even so, good diagnostic research is being done in Chiapas, where results have been promising; this effort could serve as a model for other parts of the country.

6.29 Since all the various maize growing areas need research, there must be a departure from traditional work organized along commodity and disciplinary lines. Most research should be carried out in farmers fields, with an integrated approach looking at different factors and their interactions, to identify and prioritized the factors limiting production.

6.30 While research is needed everywhere maize is grown, it will be most important in the less productive areas, which total three million ha. The main limiting factors there are agronomic and, if genetic material is to have an impact, agronomic problems have to be solved concurrently.

2. Wheat

6.31 Wheat research in Mexico is one of the great success stories of modern agriculture. In 1943 the Mexican Ministry of Agriculture, in collaboration with the Rockefeller Foundation, founded the Office of Special Studies with the aim of raising production of basic food crops in Mexico through research. As a result of this research, Mexico now cultivates wheat on about 1.0 million ha and produces 4.5 million metric tons.

6.32 The program initial goals were to introduce better-adapted varieties with resistance to rusts. These goals were met in a short time, and Mexico became self-sufficient in wheat by 1955. The Office of Special Studies was terminated in 1961; INIA continued the wheat research. CIMMYT was established in 1966 and has collaborated with INIA and, since 1985, with the newly constituted INIFAP.

6.33 Three main areas produce Mexico's wheat. The northwest grows 70 percent and the Bajio 20 percent, both on irrigated between November and May. The central highland grows rainfed wheat during the rainy summer season and accounts for 10 percent of production.

The Northwest

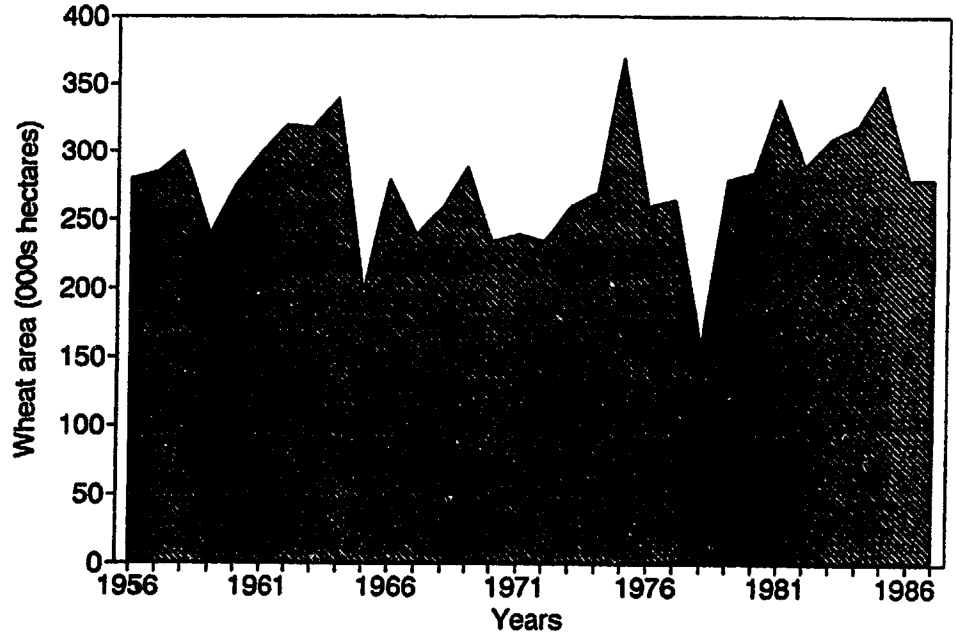
6.34 Wheat in the northwest is concentrated in the irrigated areas of the States of Sonora and Sinaloa. The area sown is about 650,000 hectares, with an annual yield of 4.6 tons/ha and total production of 3 million tons. In this area wheat is the principal crop and wheat-soybeans the most widely used cropping system (soybeans are grown in the summer). Soybeans are sown after wheat and, depending on the availability of water, the area varies widely.

6.35 Agriculture is highly commercialized. Almost all operations are mechanized with most labor used for irrigation. Market systems are well developed for inputs and products, and most farmers also receive short-term credit from official sources, private banks or credit unions. Extension is still deficient, but new varieties are adopted quickly, largely through an efficient seed distribution program.

6.36 The area sown to wheat in Sonora has settled around an average figure of 280,000 ha since the late 1950s (Figure 9). The area in Sinaloa was incorporated later than that of Sonora and has averaged 220,000 ha over the past ten years, reaching a high of 297,000 ha in 1985-86 and a low of 91,000 ha in 1987-88.

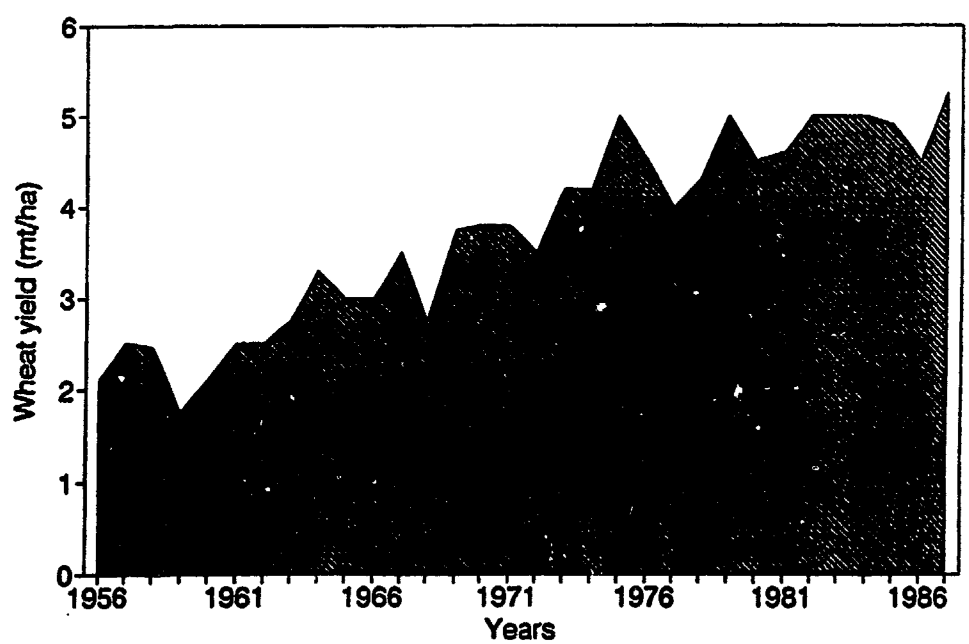
6.37 Yields are high in the northwest, averaging about 4,600 kg/ha. Yield trends for the northwest and other irrigated areas such as the Bajio are exemplified by those for Sonora (Figure 10). By the early 1960s yields had leveled off at about 2000 kg/ha. Since the varieties grown then (Lerma Rojo 54 and Nainari 60) were resistant to the rusts, the main limiting factor to yield was lodging. The introduction of semidwarf varieties in 1962 overcame this limitation and led to impressive yield gains up to 1975.

Figure 9. Mexico--wheat area in Sonora
(000s hectares)



6.38 Wheat yields in Sonora, representative of other irrigation areas, have risen at an annual rate of about 100 kg/ha over the past 30 years. This trend (Figure 10) can be broken down into two separate time components, 1962-75 and 1976-88.

Figure 10. Mexico--Wheat yield in
Sonora (mt/ha)



Research Problems

6.39 The main problems in wheat breeding for the northwest are resistance to leaf rust and to karnal bunt. Resistance to leaf rust is not stable in Mexican commercial varieties. The average life of a variety under production in the northwest is usually three to five years before resistance breakdown; this calls for a constant breeding effort to keep ahead of the disease.

6.40 Karnal bunt, first identified in India in the 1930s, appeared in Mexico in 1970. The first discovery was in southern Sonora, but by 1982 the disease had spread south into Sinaloa, where it has reached its highest infestation levels because of favorable climatic conditions. It also spread to Baja California Sur, although not to northern Sonora or to Baja California Norte.

6.41 CIMMYT has recently done a study on the economic costs of karnal bunt. The estimated total costs represent 2.1 percent of the value of production in southern Sonora, 2.0 percent in Sinaloa, and 0.3 percent in Baja California Sur. Some advances may have been made in breeding for tolerance to this disease; advanced lines available show increased tolerance but not outright resistance to karnal bunt.

Research Achievements

6.42 The main breeding program is at the Center for Research in Foods and Animal Nutrition (CIANA) station of INIFAP at Ciudad Obregon, Sonora. INIFAP has researchers, breeders, and pathologists assigned to the program, which collaborates closely with CIMMYT. Because of the breeding methodology used, the varieties from this program are widely adapted and employed in other parts of Mexico, even rainfed.

6.43 The major accomplishments of the bread wheat breeding program have been:

a. Stabilization of resistance to stem rust;

b. Incorporation of genes for photoperiod insensitivity, thus broadening adaptation of the varieties;

c. Incorporation of dwarfing genes, resulting in varieties with high yield potential and greater fertilizer response;

d. Good baking quality;

e. Release of two-gene dwarf varieties in the early 1970s, further increasing the harvest index and the yield potential;

f. Release of varieties from winter-spring crosses in the early 1980s, fortifying disease resistance and yield potential.

6.44 One study (Fischer and Wall 1975) concluded that wheat yield potential had improved by 40 percent between 1950 and 1975 if the older taller genotypes were supported against lodging or by 87 percent if they were not. A later study (Waddington et al. 1986) concluded that the average rate of increase in yield potential, where lodging was controlled, in 1950-82 was an annual 59 kg/ha or 1.1 percent.

6.45 Spectacular progress was also achieved in durum wheat. Since the mid-1980s the northwest durum area has grown (Table 6.3). Some of this is due to durum wheat's inherent resistance to karnal bunt and to the quarantine restrictions on the sowing of bread wheat in infected areas. The average area on which only durum wheat was allowed to be sown due to karnal bunt was 38,600 ha in the period 1984-89.

Table 6.3. Estimated Area of Durum Wheat in Sonora and Sinaloa
(thousand hectares)

	Sonora	Sinaloa
1984-85	54.7	0.0
1985-86	59.6	0.0
1986-87	93.6	7.6
1987-88	96.2	n.a
1988-89	80.8	27.0

Source: CIMMYT.

6.46 There have been many other important research contributions over the past 40 years, in crop and water management. Research on fertilization of wheat was one of the main features of the yield increases in the 1960s, and important research work was done on weed control. Over the past 15 years as the yield trend has leveled off (Figure 9), greater attention has gone to research aimed at reducing producer costs--seeding in preformed beds, lower seed rates, lower herbicide usage, and better water use efficiency.

Current Research

6.47 Present research efforts in the northwest are in breeding, pathology, and crop management. Breeding and pathology is dominated by the CIMMYT program, based at CIANA. INIFAP's input is limited, though of high quality. The breeding program covers the research needs of the irrigated environments of the northwest by concentrating on leaf rust resistance, karnal bunt resistance, and higher yield potential. There is a small breeding program at the Los Mochis Station that concentrates on selecting varieties for Sinaloa.

Outlook

6.48 The northwest has, for many years, been Mexico's breadbasket. With macroeconomic changes, especially the opening of the Mexican market, wheat production in the northwest irrigated lands faces challenges that will also test the agricultural research system. They come at a time of diminishing water supplies, limited land resources, and a slowing yield trend.

6.49 Water is a priority issue. Because water resources are limiting expansion of irrigation districts, further growth in production has to come from within the existing irrigation systems. Up to now this problem has received scant attention except for the development of water requirements for different crops and irrigation schedules. More in-depth studies must focus on water-use efficiency while preserving the natural resource base of soil and water. Targeting better water use across all disciplines--plant breeding, cropping systems, agronomy--this research should be based in Sonora where the problems are most immediate.

6.50 CIMMYT studies in 1983-84 found that under experimental conditions the mean yield of bread wheat cultivars was 2,300 kg/ha greater than average yield of the same varieties grown under farm conditions in the Yaqui Valley. The corresponding figure for durum wheats was about 3,000 kg/ha. While the average yield for the Yaqui Valley oscillates around 5,000 kg/ha, many farmers get yields of over 7,000 kg/ha.

6.53 Since there has been little agronomic research to identify the factors that contribute to this yield gap, this is an important area for INIFAP to tackle. It will mean a departure from research organized along commodity and disciplinary lines, and a shift toward an integrated approach looking at different factors and their interactions simultaneously. Most of this research could be done in farmers' fields and could produce a fast payoff in terms of production increase.

6.54 A further problem is the slowing of the rate of potential yield gains. CIMMYT studies have shown that up to 1982, yield potential gains had averaged 59 kg/ha/yr or 1.1 percent per year. As shown in Figure 9, yield gains are now about 1.0 percent per year. There is no reason to believe that this rate of increase cannot be maintained.

6.55 Karnal bunt is listed as the second research priority in the national program, but few resources are dedicated to solving it. The disease may never be eradicated, thus Mexican wheat production may have to learn to live with it. To do so, the country needs more information on the organism, its epidemiology, ecology, and genetic variability.

The Bajio

6.56 The Bajio, a depression in the highlands of central Mexico, has long been a traditional wheat producing area. Altitude varies from 1800 to 2000 m.a.s.l. Rainfall ranges on an increasing gradient of 400 to 800 mm from north to south; it is concentrated from May to October, with a pronounced dry season in the other six months. As in the northwest, wheat is grown under irrigation between December and May in a double-crop system with sorghum. Bajio agriculture is highly commercialized; almost all operations are mechanized and most labor is employed in irrigation.

6.57 Area and yields. Average area is 150,000 hectares with an average yield of 5,600 kg/ha--thus an average production of 850,000 tons. This places the Bajio as Mexico's second most important producing area, with about 16 percent. Yields per unit area are the highest in the country, 20 percent above the average. Ninety-eight percent of the area is now sown to one variety, Salamanca S-75.

6.58 Research problems. The Bajio's problems are different from those in other irrigated areas. Wheat is sown in a double cropping system with sorghum. The rusts, the main limiting factor in the northwest, are not so important here since conditions are not very favorable.

6.59 Scarcity of water is a significant issue. The amount of water available determines the area sown to wheat in any year, and the water table has fallen significantly in the Bajio due to pumping.

6.60 Research achievements. Since its inception in 1961 the wheat program in the Bajio has recommended about 40 varieties, not all developed on this station. The most successful variety, Salamanca S-75, was released specifically for the Bajio. Crop management practices for the Bajio have also been established.

6.61 Current research. The major part of research is centered around breeding with emphasis on the search for early, high-yielding, and disease-resistant varieties. This program is limited in what it can do and depends to a great extent on germplasm from CIMMYT. There is also a small program in crop management looking at fertilization, irrigation, and land preparation.

6.62 Outlook. Future wheat production in the Bajio faces a number of limitations. Since no more land can be incorporated into production, growth will come from increasing yields. Although the Bajio has the highest wheat yields in the country (approaching six tons per hectare), these fall short of what can be accomplished. There is no reason to believe that yield levels cannot be raised still further. To do this, there will need to be a renewed effort in agronomic research of the type not presently done. Integrated research would identify and prioritize the factors and interactions limiting production at the farm level.

6.63 Water resources, especially groundwater, are diminishing. The problem of greater water use efficiency will be more effectively tackled through agronomic research than through breeding. Research efforts to increase water use efficiency should revolve around the whole cropping system rather than around one component.

6.64 It is worrying that no advance in yield potential has been made in the 15 years since Salamanca S-75 was released--and that just one variety should occupy almost all the wheat area. The research program needs a renewed effort to identify new sources of germplasm that will fit the cropping system and further increase yield potential.

Rainfed Wheat

6.65 Historically, wheat has been produced under rainfed conditions at an altitude of between 1,700 and 2,900 m.a.s.l. in the summer cycle. The principal limiting factor is thus precipitation. The rainfed wheat area can be divided into three different categories with respect to rainfall:

a) > 600 mm
b) 400 - 600 mm
c) < 400 mm

6.66 In the Altiplano, where more than 100,000 hectares were grown in the 1950s, wheat later almost disappeared. This decline was partly due to government emphasis on promoting wheat research and production in irrigated areas and to the rise of competing crops, especially malting barley. In the past ten years, wheat has been returning to the rainfed areas. The government is projecting an increased role for rainfed wheat to as much as 1.5 million hectares by the year 2000.

6.67 Area and yields. The area sown to rainfed wheat has doubled in the past ten years (Figure 13) and in 1989 stood at 250,000 hectares. Most recent expansion occurred in the elevated potential areas of high rainfall and deep soils, notably in Jalisco (Los Altos), the State of Mexico, Tlaxcala, and Puebla. During the 1980s there was a doubling of rainfed yields to 1,800 kg/ha (Figure 13). This increase can be credited mostly to greater fertilizer use.

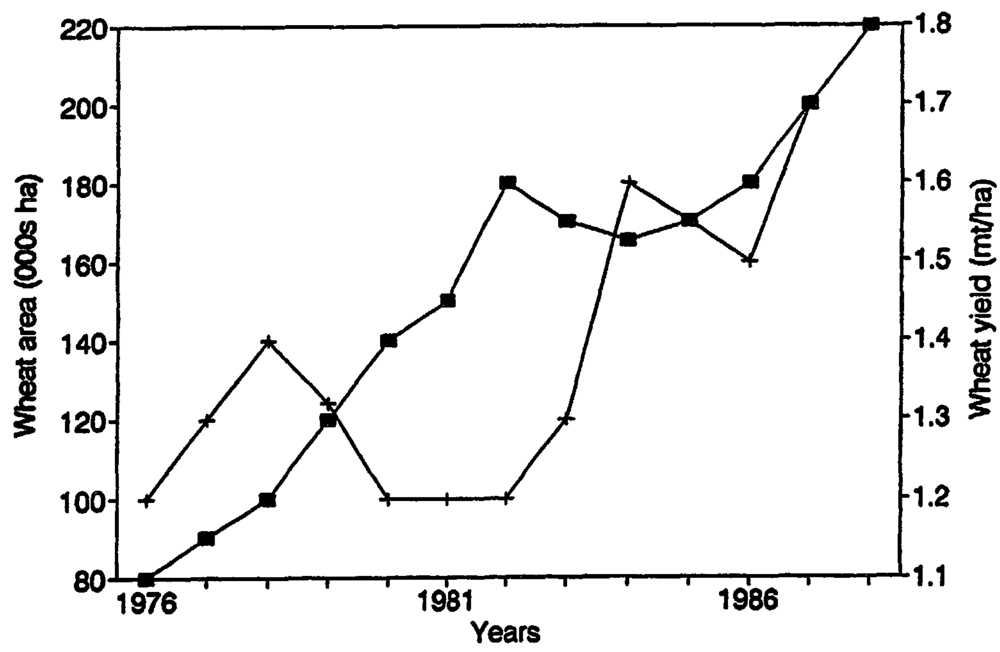
6.68 Research problems. Since wheat has a large potential in areas of precipitation greater than 600 mm, this is where expansion in the 1980s occurred. But because of the high rainfall, there are several leaf diseases that limit yield and stripe rust is also a serious problem.

6.69 Where rainfall is between 400 and 600 mm, water is a limiting factor in most years, especially if low rainfall is combined with shallow soils. Yield potential here thus lies between 2,000 and 3,000 kg/ha. Where precipitation is less than 400 mm, the distribution of rainfall is erratic, and the yield potential is only about 1,000 kg/ha.

6.70 Crop management research done by INIFAP in rainfed areas has been limited. CIMMYT has an intensive crop management program in Tlaxcala, Hidalgo, and the State of Mexico, and much data has been collected. Some of this work has been done in collaboration with the extension service and with FIRA and so has made its way to the farmer.

6.71 Research achievements. Although begun in 1969, the rainfed wheat research program received few resources until the 1980s. The program has released eight varieties, the latest being Temporalera M-87 and Galvez M-87, both in 1987. While some varieties released were important ones in terms of production (Zacatecas VT-74 and Mexico M-82), most of those sown came from the irrigated areas (Pavon 76 and Salamanca 75). The new varieties, though promising, cannot yet be judged.

Figure 11. Mexico--Rainfed wheat area and yield



6.72 Current research. Most research in breeding is based at Chapingo, with scattered testing sites, and some work also takes place in Jalisco. Although CIMMYT does not consider highland tropical wheat (Mexico's rainfed wheat) a high priority within its world mandate, it does have two important research sites, El Batan and Toluca, in the area. More emphasis is going now to getting early varieties that are high-yielding and have good baking quality--and to incorporating drought resistance for drier areas. Little agronomic research is being done on rainfed wheat, and CIMMYT has cut back crop management research on rainfed wheat in the highlands.

6.73 Outlook. Since the irrigated area under wheat will increase very little, if at all, and the yield trend line is levelling off, Mexico will have to look to rainfed regions for greater wheat production. In the better endowed rainfed area there is a large yield gap, probably 3000 kg/ha. Thus more emphasis needs to be placed on breeding material with early maturity and good disease resistance to replace the varieties brought in from irrigated areas. Disease resistance can come from CIMMYT's program but earliness is still elusive; INIFAP will have to concentrate on this trait. In the intermediate rainfall areas there are still gains to be made; the most important trait is earliness.

6.74 In the very marginal areas, the outlook for progress through breeding is less clear. There seems to be an overemphasis on breeding for rainfed wheat to the detriment of crop management, and breeding by itself will give low returns. If present area and yield trends are to be maintained in rainfed wheat, crop management should be the main approach. Many agronomic problems--fertilization, soil erosion, soil diseases, rotations--must be solved to realize fully the potential of rainfed wheat.

3. Rice

Introduction

6.75 Rice is a minor crop in Mexico. It has occupied about 165,000 ha over the last 20 years, less than 0.9 percent of national cropped area. Aggregate production is roughly 330,000 metric tons of milled rice. Average national yields have grown steadily from about 1.75 mt/ha in 1965 to 3.75 mt/ha in 1985. The yield growth has been largely attributable to greater use of fertilizer, the extension of modern varieties beginning in the 1960s, and better weed control.

6.76 Rice supplies less than two percent of average national calorie consumption, and intake has remained roughly the same since the 1950s. There has been some growth of imports in the 1980s (as much as 15 percent of consumption was imported on three occasions since 1979). A recent analysis by the Inter-American Development Bank shows that rice prices have been well below import parity prices, thus discouraging domestic production. Consumer prices are controlled below import prices by CONASUPO, so there is no incentive for private rice imports.

Production Systems

6.77 There are three principal production systems: irrigated with direct seeding, irrigated with transplanting, and tropical rainfed. The first usually occupies about 65,000 ha and contributes 50 percent of national production; the second, less than 20,000 ha and 15-20 percent of production; the third, about 80,000 ha and 30 percent of production. Federal policy since 1973 has been to promote rice production in the tropics, so as to reduce water competition between rice and other crops in the irrigated sites of the northwest.

6.78 Irrigated. Production is concentrated in the states of Sinaloa and Nayarit, with some in Jalisco, Colima, and Michoacan. Irrigation is from dams or surface diversion; nearly all the crop is planted in summer, and planting is by direct seeding or transplantation from nurseries. All operations but harvesting are mechanized.

6.79 Agronomic packages for rice production are well defined in both irrigated systems and upland conditions. They include recommendations for land preparation, seedlings density for transplanting, seeding density for direct sowing, fertility, weed control, irrigation timing in the irrigated systems, and rain water management in upland rice.

6.80 PRONASE is the principal seed supplier. In 1985-89 it produced enough seed to plant nearly all the national rice area, but sold only enough to plant 72 percent of that area.

6.81 Rainfed. Rainfed rice production is in Veracruz, Tabasco, Oaxaca, Chiapas, and Campeche. There has been a strong shift among states since 1970; production in Oaxaca has fallen to almost nothing while that in Campeche has soared. Yields are lower than the irrigated crop and the rate of crop failure is higher because of drought. All operations but harvesting are mechanized.

Limiting Factors in Rice Production

6.82 INIFAP scientists have identified rice production problems by principal growing region.

a. Northwest. In the Valleys of Mexicali and Culiacan, water supply is limiting. This is compounded by salinity and by infestations of red rice (*Oryza rufipogon*). Varieties in current use (Navalato A-71 and the Culiacan series) are planted between June 15 and July 31; with those planting dates, especially later ones, the typical cycle of 135 days is too long. INIFAP researchers believe that the gap between the best rice production potential (roughly 8.5 mt/ha of paddy) and the average yield of 4.5 mt is due to late planting, suboptimal fertilizer use, and weed infestations.

b. Northeast. In what is known as Las Huastecas (parts of Tamaulipas, San Luis Potosi, and the north of Veracruz), weed infestations, soil quality and management, and blast (*Pyricularia oryzae*) are major problems.

c. Southeast. In this zone most production is rainfed and the irregularity of rain reduces yields. Drought is a more severe problem in Yucatan than in the Papaloapan basin. Diseases, notably blast, are more important in the tropics, and Johnson grass and red rice are limiting factors in some places. The rapid development of weeds, causing greater early season competition with the rice plant, has been the focus of some rice research, including development of low-dosage herbicide recommendations. Research on water management has led to a terracing system to conserve water in the field while reducing soil erosion.

Research Systems

6.83 Rice research in the north began in 1949. INIA's summary of its rice work before the mid-1970s (INIA 1976) shows that it concentrated on varieties appropriate for irrigation with direct seeding in areas like Sinaloa. According to the 1976 INIA review, one new variety was released from 1960-64, four from 1965-70, and seven from 1971-76. Diffusion of INIA varieties from 1968 to 1975, in addition to agronomic practices and greater use of fertilizers, apparently raised yields significantly. IR8 (known as Milagro Filipino in Mexico) was introduced in 1968 and was later used in the national breeding programs but left commercial use by 1976. To date, INIA/INIFAP have released six varieties for irrigation with transplanting, seven for irrigation with direct seeding, and seven for rainfed.

6.84 Agronomic practices have included seeding density and dates, rates and dates of fertilizer application, irrigation management, soil preparation, and control of red rice. Recent agronomy work has concentrated on reducing the water consumption of the rice crop, in view of competition from more remunerative crops, notably soybean. One successful technique (entable) leaves standing water in the field, thus reducing water use by half.

6.85 Earlier rice research for rainfed systems derived from irrigated work: the breeding materials were often the same, and so were most agronomic techniques other than transplanting and those directed to field water supply. Under tropical rainfed conditions, the materials produced lower yields due to greater water stress and disease pressure. As one example, Veracruz, which grows half of Mexico's rainfed rice, reported that varieties with yield potential of 5.0 mt/ha gave less than 3.0 mt in the field (INIA 1976, p. 74).

6.86 In the southeast early research for upland rice was derived from the irrigated direct seeding system. Before (1973-1979) the breeding materials (Sinaloa A68 and Navolato A71) were planted in the Southeast and some of the agronomic techniques were the same, with the exception of water management that in the upland system is supplied through the rains. Under tropical upland conditions these varieties gave lower yields due to greater water stress and disease pressure. In Veracruz, Tabasco, and Campeche, which grow more than 90 percent of Mexico's upland rice, lowland varieties from Sinaloa state with yield potential of more than 5.0 mt/ha gave less than 3.0 mt (INIA 1976). Since drought and blast are serious barriers in tropical upland rice production, the breeding work in the early 1980s was to identify sources of resistance. Other objectives have been to incorporate intermediate stature, rapid early growth, and earliness. Agronomic objectives have been to develop fertilizer recommendations, weed control, rain water management, and insect and disease control.

6.87 Current rice research in INIFAP. This research is strongly focused on irrigated systems with germplasm evaluation/plant breeding as the principal technique (Table 6.4).[2] Since there is little movement of rice germplasm in Mexico and limited evaluation work for rainfed areas can be done at irrigated sites, there will not be significant spillover between different production systems as there appears to be in wheat.

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[2] In Table 6.4, experiments are classed only as irrigated if irrigation is mentioned in the experiment title; however, since most of the work is in Sinaloa, where rice production is uneconomic without irrigation, it is evident that the work is for irrigated systems.

Table 6.4. INIFAP Rice Experiments in 1989/90

Type	Non-Specific	Irrigated	Rainfed	Total
Germplasm	61	9	18	88
Agronomy	4	9	3	16
Physiology	0	0	0	0
Drought	0	0	0	0
Rhizobium	0	0	0	0
Seed	5	0	0	5
Plant	4	0	0	4
Agrosystem	7	10	0	17
Entomology	4	0	0	4
Weeds	8	5	4	17
Cold	6	0	0	6
Genetic resources	2	0	0	2
Methodology	2	0	0	2
Other	3	0	0	3
Total	106	33	25	164

Source: INIFAP.

6.88 Another characteristic of rice research is INIFAP is the focus on evaluation of germplasm.[3] INIFAP's sources of germplasm include materials from CIAT, the International Rice Research Institute (IRRI), and the state of Texas. These and experience with IR8 provide a wide basis for germplasm work. The recent introduction of the variety Huimangillo A-88 for the state of Tabasco, for example, resulted from collaboration among INIFAP, CIAT, and the national program of Colombia.

6.89 There is little explicit concentration, however, on such problems as entomology, plant pathology, and physiology. While those topics can be addressed as part of the regular breeder's evaluation of experimental materials, INIFAP is not doing enough work on them, largely for lack of resources.

4. Sorghum

Introduction

6.90 Sorghum is a prominent example of Mexico's ability to adapt foreign technology to national conditions. In 1955 when the first sorghum hybrids were developed in the U.S., little sorghum was grown in Mexico. By 1970, the Mexican sorghum area totaled 1.0 million ha today it is 1.5 million ha. Average national yields of 1.8 mt/ha in 1960 grew to more than 3.0 mt/ha by 1980, and now exceed 3.2 mt/ha. The best irrigated summer yields can exceed 10 mt; rainfed yields, both summer and winter, often surpass 3.0 mt. Commercial hybrids are Mexico's main seed source

[3] There is some adaptive mechanization work in Morelos on transplanters and harvesters.

in the country, with PRONASE supplying less than five percent of the sorghum area. INIFAP estimates that the share of foreign material in commercial hybrids is 95 percent, thus this material remains the force behind the remarkable expansion of sorghum.

6.91 Sorghum growth was stimulated by the availability of imported hybrids, by the crop's ability to yield better than its competitors under rainfed conditions, by the expansion of irrigation, and by economic growth that induced consumer demand for livestock fed with grain. Sorghum is also well adapted to diverse production systems and growing seasons (Table 6.5). Perhaps 30 percent of the cultivated area is irrigated, one third of that in winter. About half of rainfed sorghum is grown in summer and half in winter. While nearly all of the rainfed winter crop is in Tamaulipas, the summer crop is widely distributed throughout Jalisco, Guanajuato, Michoacan, and Sinaloa. In rainfed sites, sorghum has given higher yields than the competing crops maize, beans, and forages.

6.92 Most of Mexico's sorghum is of the red grain type and is used in feed production. Greater domestic production of poultry, pork, and eggs in the 1960s and 1970s came partly from sorghum feed grain, and much growth in the national processed feed market consisted of increased sorghum use. Despite this domestic success, however, sorghum imports have grown rapidly and now account for about 25 percent of use.

6.93 Protection has had little specific effect on sorghum production. In 1958-83, typical nominal protection coefficients (NPCs) were about 1.0 on market producer prices. Since 1984, the average has been 1.27, indicating greater protection. This has apparently been achieved not by raising the government guarantee prices but by unofficial import restrictions.

Production Systems

6.94 Most winter production takes place in Tamaulipas, which accounts for 91 percent of the crops. As to summer crop, Guanajuato produces 36 percent, Jalisco 22 percent, and Michoacan 15 percent.

6.95 Irrigated production. Irrigated sorghum began to develop at the end of the 1950s in the north-center of Mexico; in the Bajio it has displaced maize and chickpea. Sorghum is produced with commercialized systems that employ mechanization, high fertilizer levels, and good management. The type of irrigation affects yields. In Guanajuato and Jalisco some farmers employ the recommended number of three for summer production. Those who use punto de riego, essentially one supplementary irrigation late in the crop's cycle, get lower yields than those who use full irrigation.

6.96 State yields average more than 5 mt/ha and some producers may get as much as 10-12 mt/ha. In Guanajuato, the best state for summer production, the mean yield with irrigation in 1985 was nearly 6.9 mt/ha; in Jalisco, only 4.8. The spring irrigated average in Tamaulipas is about 3.2 mt/ha.

6.97 Winter rainfed. This production takes place essentially in Tamaulipas, where there is no critical danger of frost and rain is adequate. Yields in this system, mainly in the north of Tamaulipas, are lower than with irrigation, but sophisticated production techniques have been developed. These include near complete mechanization, land management to preserve soil moisture, chemical and mechanical weed control, and detailed fertilizer recommendations.

6.98 Winter yield potential in Tamaulipas is roughly 5 mt/ha, while current yields are 2.0-2.5 mt. Scientists at the Rio Bravo experiment station, at the extreme north of the state, attribute the difference to environmental factors--frost, hail, stalk rot, midge, and head smuts--and to agronomic practices such as poor plowing, inappropriate densities, and inadequate chemical use.

6.99 Summer rainfed temperate. This growth takes place in Jalisco, Guanajuato, Michoacan, and Sinaloa. In Guanajuato, rainfed sorghum is a monocrop or occasionally rotates with maize or forage chickpea, since soil moisture does not permit two crops. A complete production package has been developed, including recommendations on seed, density, pest control, fertility, and cropping calendar. Optimal yields appear to be about 7.5 mt/ha. ICRISAT trials of elite cold-tolerant materials for this environment give average yields of 5 mt/ha.

6.100 Summer rainfed tropical. This takes place in coastal parts of Jalisco, Chiapas, Colima, and Michoacan.

Research Systems

6.101 The allocation of resources in the sorghum network is 10 percent for the north (largely rainfed in Tamaulipas), 25 percent for the center (mainly Guanajuato and Jalisco), and 60 percent for the south. Current emphasis derives from recognition that much of the north can do adaptive work with U.S. materials, that central Mexico already has sophisticated systems with high yields, and that sorghum is relatively new in the south. This allocation of research resources is a change from past orientation, which concentrated on the north and the Bajio. The shift also results from recognizing that commercial hybrids have not done well in the south and that private companies are not working there.

6.102 The main technique in INIFAP sorghum research is plant breeding (Table 6.5), which accounts for about 60 percent of reported experiments. Seed production and evaluation make up another 11 percent. There are no specific projects for drought resistance and only three for cold tolerance.

6.103 About half of INIFAP sorghum research is done in Sinaloa, Tamaulipas, and Guanajuato, the rest being widely dispersed (Table 6.7). This appears largely out of step with the distribution of sorghum production. Even so, there may be good possibilities for using materials developed at a few sites, with irrigation, for use elsewhere.

6.104 Irrigated production. The early effort of the sorghum breeding program was directed to irrigated areas. Begun in the late 1950s, the program released its first hybrids in 1972; the six initial hybrids were planted by 1976 on 30,000 hectares, or about 2.5 percent of the national sorghum area.

6.105 Winter rainfed. Early work here concentrated on Tamaulipas state at the Rio Bravo experimental station. It grew out of the maize/sorghum program and was designed to adapt Texas sorghums to Mexican conditions. This research developed the RB2000 and RB3000 series of hybrids; the more recent RB4000 has different parentage and may require different agronomic recommendations. Irrigated materials are used in rainfed because specific hybrids are not developed for rainfed conditions, thus tending to lower yields over time.

6.106 Summer rainfed temperate. Early work before widespread introduction of U.S. hybrids at in the lat 1950s concentrated in the low to intermediate highlands. With creation of INIA in 1961, a joint INIA/CIMMYT/Chapingo program began to work on cold tolerant varieties for higher zones; it released three varieties. The 1976 INIA review of research results concluded that sorghum was not necessarily more competitive than maize in the drier parts of this environment because of sorghum's lack of cold tolerance. Work on cold tolerance continues to the present.

6.107 ICRISAT work has emphasized cold tolerance in the intermediate highlands. Beginning in the late 1970s, it has tried to achieve early maturity with cold tolerance against early frosts, acceptable grain quality for food use, and a plant type that can be harvested mechanically. Although nine varieties containing material from ICRISAT had been released in Mexico and Central America by 1986, this program appears to have had limited impact on cold tolerance.

6.108 Summer rainfed tropical. Almost no initial INIA sorghum work was done for the tropics. Recent work has tried to produce food types with low tannin content and good cooking quality, in the Pacific Coast states and in the south. INIFAP sorghum scientists argue that change toward the south may permit quick progress because breeding materials from the north and from the exterior can be adapted to the tropics. Indeed, some hybrids have already been developed for both the dry and wet tropics.

6.109 Recent ICRISAT work emphasizes the drier tropics, notably to achieve "early maturity to stabilize grain yield in drought prone areas". ICRISAT in Mexico uses Indian material as sources for breeding material and for resistance to local diseases. Greater emphasis is placed on disease resistance because of the greater disease pressure in tropical areas. This program has been more successful than the highland one because of the wider availability of tropical germplasm from ICRISAT. Several materials were released in Mexico and Central America from 1980 to 1988, from the ICRISAT or in collaboration with the International Sorghum and Millet Project (INTSORMIL).

Special Topics

6.110 Sources of germplasm. Sources of germplasm are many. They include ICRISAT, INTSORMIL, American universities, and, in some instances, private companies. Materials from other Latin American countries have been tried but found wanting. New materials are used as the basis of breeding programs and to incorporate novel characteristics (cold tolerance, low tannin content in red grain types, and earliness for frost escape in summer plantings). ICRISAT has a regional germplasm bank at CIMMYT that can be used by national research programs throughout the subregion. Mexican universities and seed companies do sorghum research. The universities of Nuevo Leon and of Guadalajara have apparently released both varieties and hybrids.

6.111 Competition between sorghum and maize. Various efforts are being made to substitute food sorghums for maize in the states of the Pacific Coast and the tropical south. This work is linked to development of white grain types and to the improvement of food characteristics. Since most sorghum in Mexico is of the red grain (high tannin) type, it is not desirable for human consumption. INIFAP and ICRISAT have programs to develop white sorghums as alternative food crops for marginal rainfed areas.

6.115 Use of irrigated materials in rainfed production and research. The development of materials for rainfed production under irrigated conditions is common. In the CIFAP of Tamaulipas, where most sorghum production is rainfed, a common material (RB 3030) was developed for irrigated

conditions but is widely used in rainfed. Something like this is also done in Guanajuato state, where about half of production is rainfed and half irrigated; there, irrigated materials dominate but reportedly do badly under rainfed conditions in drought years.

Table 6.5. Sorghum Environments in Mexico

	Winter Rainfed	Summer Irrigated	Rainfed	Irrigated
Area ('000 ha)	700	200	400	750
Ecology	Temperate	Temperate Tropical	Highland; Temperate	Highland
Grain Type Maturity	Red	Red	Red;White	Red
Rainfall	400-600 mm	Irrigated	600-1500	Irrigated

Source: INIFAP.

Table 6.6. INIFAP Sorghum Experiments in 1989/90 by Theme

	Principal production system			
	Mixed	Irrigated	Rainfed	Total
Germplasm Evaluation	109	26	11	146
Agronomy	26	9	0	35
Seed	20	2	4	26
Pathology	7	0	0	7
Agrosystems	17	0	1	18
Entomology	11	2	0	13
Weeds	5	1	0	6
Cold Tolerance	3	0	0	3
Other				
Total	198	40	16	254

Source: INIFAP.

Table 6.7. INIFAP Sorghum Experiments in 1989/90 by State

	Shares	Total Number	Germplasm Evaluation	Agronomy	Seed Production	Plant Pathology	Agrosystems & Economics	Entomology	Weeds	Cold Tolerance
Sinaloa	22.8%	58	46	2	4	1	1	2	2	
Tamaulipas	15.4%	39	8	7	2	5	6	11		
Guanajuato	11.8%	30	21	2	5	2				
Veracruz	6.7%	17	7	6			4			
Jalisco	5.1%	13	10	1	1	1				
Tabasco	5.1%	13	7	4					2	
Mexico	4.3%	11	8							3
Region Panuco	3.9%	10	6	1	2		1			
Oaxaca	3.1%	8	5				3			
Nuevo Leon	2.4%	6	2		4					
Aguascalientes	1.6%	4	2	1	1					
Campeche	1.6%	4	1	1	1		1			
Colima	1.6%	4	3		1					
Durango	1.6%	4	4							
Region Lagunera	1.6%	4	3		1					
San Luis Potosi	1.6%	4	1	2	1					
Yucatan	1.6%	4		3			1			
Chihuahua	1.2%	3	3							
Michoacan	1.2%	3	3							
Sonora	1.2%	3	1		2					
Baja California	0.8%	2		2						
Chiapas	0.8%	2	1	1						
Puebla	0.8%	2	2							
Queretaro	0.8%	2		1			1			
Guerrero	0.4%	1	1							
Nayarit	0.4%	1			1					
Quintana Roo	0.4%	1		1						
Zacatecas	0.4%	1	1							
Baja California N.		0								
Coahuila		0								
Distrito Federal		0								
Hidalgo		0								
Morelos		0								
Tlaxcala		0								
Total		254	146	35	26	7	18	13	6	3

Source: INIFAP.

Box 3. The Economics of Plant Breeding

The most successful agricultural research in Mexico has been in plant breeding. The focus in most crops remains on some form of research using breeding techniques. Little is known about the returns to this work, however, except from estimates of aggregate returns to research on particular commodities.

Brennan (1988) has recently devised a method for the economic analysis of plant breeding programs. The method describes the generational sequence of an improvement program and assigns costs to each step in the sequence. After projecting future yield and quality gains resulting from the program, it values gains at market or international prices. Cost-benefit analysis is then done of the results. Applications of the method include estimating the appropriate size of research programs for given crops, the location of research, and priorities among crops in allocating fixed research resources.

Using this method, appropriate sizes of breeding programs in Mexico were calculated under assumptions about yield growth in major commodities. The commodities modeled are beans, maize, rice, sorghum, and wheat. These crops are the basis of Mexican staple consumption and cover about 70 percent of the cropped area, thus defining priorities in them is crucial for public research.

<u>What size of breeding program would be justified by historical growth in yields</u>? Historical yield growth in these crops has varied from a low of 2.3 percent in beans to a high of 4.8 percent in wheat over the period 1950-85. In the model, half the historical gains are attributed to the direct effect of plant breeding efforts and half to associated research, extension, and input use. These yield improvements from breeding, valued at Mexican producer prices, would justify crop improvement programs with staff sizes as shown in Box 4 Table.

<u>Should resources be put into irrigated or into rainfed research</u>? At historical rates of yield growth, resources would be used more efficiently in rainfed production systems for beans and maize and in irrigated for rice, sorghum, and wheat. Despite the faster yield growth for beans and maize under irrigated conditions, most production occurs under rainfed conditions and this makes the overall benefits to research greater in those conditions.

<u>How do the suggested resource allocations compare to those in the INIFAP portfolio</u>? Obviously, the shares of sorghum and wheat would be much higher and those of beans and rice much lower if model results guided research priorities. However, the congruence indicators are high, 0.85 for rainfed production and 0.92 for irrigated. The indicator with respect to planned experiments is 0.87. It is appropriate that the shares of sorghum and wheat be lower than those suggested by congruence with rates of return, because the possibility of importing research is great in those crops. Hence, it is logical that Mexico allocate its own research resources to rainfed bean and maize production, for which the contributions of private and international research are smaller and that it neglect sorghum and wheat, whose technical changes can be imported.

Box 3 Table. Sizes of Breeding Programs That Could Be Justified at Specified Rates of Yield Growth
(Man-Years)

Crop	Irrigated production Rates of yield growth Annual % Historical	2%	4%	Rainfed production Rates of yield growth Annual % Historical	2%	4%
Beans	19	11	23	42	25	51
Maize	287	80	167	462	135	
278						
Rice	23	11	24	6	3	6
Sorghum	329	53	112	246	44	91
Wheat	273	72	152	10	3	6

Congruence of those Programs with Materials Released and Planned Experiments

Materials Released	Irrigated Numbers	Shares	Rainfed Numbers	Shares
Beans	66	18%	58	20%
Maize	101	27%	107	38%
Rice	28	7%	6	2%
Sorghum	50	13%	47	17%
Wheat	131	35%	66	23%
Total	376	284		
Congruence	.92	.85		

Planned Experiments, Rainfed and Irrigated, 1990-94

Beans	2,448	12%
Maize	9,840	48%
Rice	4,804	23%
Wheat	1,461	7%
Other basics	2,026	10%
Total	20,579	
Congruence	.87	

B. Grain Legumes[4]

6.116 The principal grain legumes of Mexico are dry edible beans (Phaseolus vulgaris L.), soybean (Glycine max (L.) Merr.), chickpea (Cicer arietinum L.), and lentils (Lens esculenta L.). The total production of beans, soybeans, and chickpeas from 1966 to 1985 was roughly 1.8 million metric tons per year. In 1985, they occupied 2.38 million hectares, or 14.4 percent of the cropped area.

6.117 There have been some rapid shifts in area, yield, output, and price of these crops. National bean area and yields have not changed, but bean prices have been very unstable without any strong trend in real terms. Soybean area has grown from less than 5,000 ha in 1960 to 375,000 ha in the 1980s; prices have been more stable than those of beans but have also shown no real trend.

1. Beans

6.118 Beans (Phaseolus vulgaris L.) are a staple food of the Mexican people. Maize and beans provided about 60 percent of calories and protein in the diet from 1950 to 1985. Beans provide more of the intake, especially of protein, of poorer people. In rural areas, maize tortillas and beans may supply 75 percent of calories and 80 percent of protein. The importance of beans in the diet has probably fallen a bit since 1950.

6.119 National bean production has hovered around 1.0 million mt for the past 25 years. During that period total area was roughly 1.62 million ha, with no change from 1966 to 1985. Average national yields grew slowly from 1950 (0.25 mt/ha) to about 0.5 mt/ha in the 1960s, where they have stayed. In 1985, irrigated yields were about 1.2 mt/ha and rainfed were about 0.45.

6.120 Bean production is both irrigated and rainfed. About 20 percent of national output is with irrigation. In 1985 there were 35,000 irrigated ha harvested in the fall-winter cycle and another 105,000 in the spring-summer cycle. The principal state in the fall-winter cycle is Sinaloa and in the spring-summer cycle Zacatecas. Rainfed production is concentrated in the states of Zacatecas, Chihuahua, Guanajuato, and Durango--a shift from Chiapas, Guanajuato, Michoacan, and Jalisco. In 1985 about 100,000 ha was harvested in the fall-winter cycle in the more tropical states. However, most of the national bean area is harvested in the spring-summer--in 1985, 1.53 million ha. While expansion of irrigated areas contributed to the growth of yields until about 1965, it has not done so since.

6.121 For many years, Mexico rarely imported beans and occasionally exported them. In 1980 the picture changed, and Mexico has been a net importer of beans for the past 10 years (Acosta 1988a and 1988b), though still nearly 90 percent self-sufficient in beans. The growth of imports has occurred despite falling per capita consumption.

6.122 One official response to higher imports has been to raise the guarantee prices; real bean prices have gone up substantially in the last 10 years. As measured by producer prices, beans are now among the most expensive of the five major crops in Mexico. From 1966 to 1985 the average ratios of bean prices, in pesos per calorie, to those of maize, wheat, sorghum, and rice were 0.96, 1.19, 1.33, and 0.77; in pesos per unit of protein, the ratios were 2.70, 2.33, 3.75, and 3.43.

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[4] This section is derived from the work of Robert Henson (consultant). Chickpea and lentil research are discussed in Annex 3 of the Technical File for this Report but not here for reasons of space.

In spite of better prices for beans, no supply response has been seen in area or in total production since 1965.

6.123 Research has had little sustained impact on bean production. What growth there has been in yields is due to irrigation not to better rainfed yields. One hypothesis of Mexican scientists is that competing crops have forced bean area onto more marginal lands. If this is true, then one would expect to see (a) a fall in the proportion of bean area grown with irrigation, or (b) a rise in the shares of rainfed bean area in more marginal states.

6.124 From 1977 to 1985 there was no trend in the proportions of irrigated to total bean area. From 1972 to 1985 there was some variation in the fall-winter area (most of which is irrigated), but not very much. The main producing state is Zacatecas, which has a relatively small irrigated area in the national total. There appears to have been little change in the shares of bean in total sown areas in more marginal states. It is possible that a shift to poorer lands has occurred within states, but available data do not allow us to examine this.

Northwest

6.125 Production systems. Beans are a winter crop in the northwestern states of Sonora and Sinaloa. Preferred seed types are Bayo (cream-colored, oblong seed), canario (cream-colored, oblong seed), and azufrado (yellowish, more rounded seeds). There are some pinto (oblong, flat, cream-colored background with dark spots) and black (small, opaque) types. The normal growth cycle is 100-120 days. Certified seed (brought from central Mexico) is widely available. Seed storage under ambient conditions is satisfactory.

6.126 Sinaloa normally grows between 105,000 and 180,000 ha. The area may be as small as 40,000-50,000 ha when the market price is very low. In northern Sinaloa, the normal planting time is September/October, but in areas benefited by cool sea breezes, 15,000-20,000 ha are planted to a second crop in February/March.

6.127 The most concentrated areas of production in Sinaloa are under irrigation around Los Mochis (north) and Culiacan (central). The northern and southern zones produce primarily beans, while the central zone also grows soybeans and chickpeas. The normal crop rotation in the Culiacan area includes soybeans or rice in summer and beans, wheat, horticultural crops, or sorghum in winter. Soybean production is totally mechanized, but the bean harvest is not.

6.128 Beans in southern Sinaloa are produced on 30,000-35,000 ha, almost exclusively on residual moisture. After the rainy season (July to late September), fields are tilled and later compacted to restrict soil moisture loss by evaporation. The crop is planted when the weather cools, at the end of October or, more commonly, in November. Since the crop is grown under relatively dry conditions, there are few problems with diseases and insects. The majority of farmers do not use fertilizer.

6.129 In the south, beans are normally grown in rotation with broom sorghum or maize. Since beans are the most important component of the cropping system, maize and sorghum are planted after beans so as not to interfere with planting beans at the optimum time. Bean yields are stable at 600-1,000 kg/ha. Seed types include azufrado, Bayo, and Peruano; a small, irrigated area is planted to black beans for export to Mexico City. The higher yield of the blacks compensates for the lower market price. The azufrado type is the most popular for consumption in southern Sinaloa. The landrace varieties yield as well or better than cultivars released by the experiment station. This superiority has been attributed to the more prostrate growth habit of the landraces resulting in better soil coverage and in reduced evaporation.

6.130 Research systems. Bean research at the San Ignacio Experiment Station, Navojoa, Rio Mayo Valley, Sonora, began in 1980. The main activity is evaluating breeding lines from Los Mochis for yield, adaptation, and resistance to viruses and rust. These trials have established that pinto beans are susceptible to rust and that viral infection is generally lower in indeterminate plants than in determinates.

6.131 Bean research in the Valle del Fuerte, Sinaloa, began in 1956. The experiment station in Los Mochis is currently the center for bean breeding for the northwest. The research staff consists of three breeders, including the INIFAP expert for the north region of the grain legume network.

6.132 The objectives of technology generation are to increase yield and input use efficiency and to decrease irrigation usage. Objectives for maize include: inputing use so as to decrease production costs; increasing the intensive use of the soil; and raising product quality. Objectives for rainfed areas include: characterizing the agroclimate; using the total growing season; studying factors associated with yield; studying crop protection; identifying alternative crops; and integrating crop and livestock production.

6.133 Specific breeding program objectives in Los Mochis are to identify high-yielding, adapted germplasm with resistance to local viruses and rust in an erect plant type. The formation of improved varieties for irrigated production began in Culiacan in 1961. Due to the current emphasis on research with soybeans and chickpeas at this site, bean work is limited to little more than evaluating advanced lines in regional network trials. In addition, since all bean experiments in Culiacan are conducted 20 kilometers from the experiment station (on alluvial soils typical of that in the surrounding production areas), lack of vehicles and gasoline limits the installation, maintenance, and observation of field trials.

6.134 The bean research team consists of one full-time breeder, a part-time entomologist, and a part-time production systems agronomist. Researchers in Mazatlan evaluate segregating populations and do not release varieties.

6.135 The northwest germplasm evaluation network is set up as follows:

- Initial crosses and advances to F3 are done in Los Mochis.

- In the F3 and F4 generations, researchers from Baja California Sur, Navojoa, Los Mochis, Culiacan, Mazatlan, and Nayarit inspect materials in the field at Los Mochis and select lines.

- The selections of each researcher (now F5) are put into the Adaptation Nursery (Vivero de Adaptacion or VA) and planted at each site. Multilocational results are compiled at Los Mochis.

- Those lines yielding better than . .e controls in the VA enter specific selection programs at each site (Local Trial or LT). The best lines overall in the VA (now F6) enter the Regional Trial (RT), again at each site.

- The best lines overall in the RT enter the Uniform Trial (UT) at F7, again at all sites (the best lines from the LT are used as local checks, and the most widely planted varieties in the region are included as regional checks).

- The Unidad de Programacion y Evaluacion Regional inspects the results of the UT. If a line yields at least 10 percent better than any regional check, it enters the UT a second year. If the line again yields at least 10 percent better than any regional check, it may be released as a variety for the region. When a line enters the UT for the second year, agronomic crop management experiments are begun on the line (fertilization, irrigation, plant population) at two or three irrigated sites.

6.136 When a line is released as a variety, breeder's seed is given to PRONASE and the Comision Permanente de Investigaciones Agricolas del Estado de Sinaloa for production of foundation, registered, and certified seed. If there is a large quantity of breeder's seed, the foundation seed step may be omitted. Researchers plant demonstration plots with the new varieties (the extension service does not have sufficient resources to put in trials).

6.137 Research achievements. Since 1966, CIFAP-Sinaloa has released bean varieties in the canario (3), azufrado (7), black (2), and pinto (1) seed types. The variety Azufrado Pimono-78 is currently planted on 80 percent of the state bean area. In evaluation trials, Azufrado Regional-87 and Azufrado Peruano-87 have produced 10-15 percent higher yields than Azufrado Pimono-78, and are also expected to have a large impact on production.

6.138 In Mazatlan, the effects of fertilization on bean yield have been studied and recommendations developed of 40 kg N/ha for sandy soils and no fertilizer (no response to fertilizer was detected in research trials) for alluvial soils (the predominant type in the area).

6.139 Research cooperation. CIFAP-Sinaloa cooperates with CGIAR centers by evaluating lines of beans (CIAT), lentils (the International Center for Agricultural Research in Dryland Areas--ICARDA), and chickpeas (ICRISAT and ICARDA). CIAT scientists occasionally visit Culiacan. The 10 farmer organizations in the state currently contribute about eight percent of the costs of research.

6.140 Current problems. Diseases limit bean production in southern Sonora and northern Sinaloa. Bean golden mosaic virus (BGMV) and bean chlorotic mottle virus (transmitted by white flies), bean southern mosaic virus, and bean curly dwarf mosaic virus (transmitted by Diabrotica spp.) are the most prevalent. Rust and Sclerotinia may become serious under conditions of humidity and cool temperature, especially in January and February. A number of very promising, disease-resistant lines from the breeding program are entering advanced regional trials.

6.141 High harvest costs (30-55 percent of total production costs) due to expensive labor reduce profits and the area planted to beans. Statewide harvest losses average 10-15 percent of production; some producers harvest by direct combining, preferring 30-40 percent harvest losses to the high costs of manual harvesting. Increased production of horticultural crops in the area has resulted in higher costs and reduced availability of hand labor. The bean breeding program in Los

Mochis is developing lines with a more erect plant type to facilitate mechanical harvesting. Research is being conducted in Veracruz on totally mechanizing the bean harvest (which would reduce costs), but a viable system has not been developed. Certified seed of new varieties tends to become contaminated at harvest because the combines move from normal production fields to seed fields without proper cleaning.

6.142 In southern Sinaloa, drought is the most important factor limiting bean production (rain falls during the bean growing season about once every five years). Current research is studying planting depth and plant spacing to better manage available soil water in the system of residual moisture production, but shorter-season varieties and germplasm are needed.

El Bajio

6.143 Production systems. In the past, much of the bean crop in Guanajuato was an intercrop with maize. The maize yield in this system is greater than that of beans (maize is the more important crop). Lately, the traditional intercrop has been displaced by maize and bean sole crops. Twenty years ago 50 percent of the area planted to beans was maize/bean intercropping; the figure is now approximately 15-20 percent.

6.144 Beans are grown under irrigation on 130,000 ha and under rainfed conditions on 10,000 ha. Rainfed yields are low, ranging from 300 to 400 kg/ha; irrigated yields are 1,100-1,200 kg/ha. Irrigated beans are normally fertilized with 40 kg/ha N and 60 kg/ha P. Due to the higher risk, rainfed beans are usually not fertilized. In 1986, the state produced an excess of 1,347 tons, while in 1987 beans were imported from other states to meet demand. Annual per capita consumption is 13 kg.

6.145 The most popular type is Flor de Mayo, which occupies 80 percent of the area in Guanajuato. Other types grown include Canario, Cacahuate, and Bayo in irrigated areas and Canario, Bayo, Bayo Rata, Rosita, and Mayocoba (Azufrado) under rainfed conditions. Irrigated beans are ridge-planted in February in the central-south region and in the beginning of March in the north.

Table 6.8. Bean Breeding Research

Region	Principal Bean Type	Principal Source of Germplasm	Principal Breeding Site
Northwest	Azufrado, Bayo, Canario	Mexican Collection at Chapingo	Los Mochis
Bajio Central	Flor de Mayo	CIAT, Chapingo	Celaya
North Central	Ojo de Cabra	CIAT, Chapingo	Casas Grandes, Aguascalientes
Southern	Black	CIAT, Guatemala	Tuxtla Gutierrez

Source: Mission interviews.

6.146 Research systems. Beans are a high priority crop in Guanajuato. In 1975, bean research at the Bajio Experiment Station began to breed for resistance to bean common mosaic virus (BCMV) in black beans, thus the release of the variety Negrocel. Breeding within the Flor de Mayo type began in 1976; the variety Flor de Mayo RMC (resistant to BCMV) was released in 1981.

6.147 Objectives of research on the Flor de Mayo type include resistance to BCMV and common bacterial blight, yield, varieties with a 90-100 day cycle and a yield potential of 2,500-3,000 kg/ha. Specific research objectives for rainfed production include resistance to drought, rust, and BCMV; seed quality and nitrogen fixation; and raising yield levels to 1,000-1,500 kg/ha.

6.148 A grain quality lab has been set up at the Celaya Experiment Station. It will study protein concentration in beans and garbanzos, and cooking time and cooking X storage interactions in beans. Researchers throughout Mexico are encouraged to submit advanced lines for analysis to avoid spending resources on developing varieties that will not be accepted for culinary reasons.

6.149 Research achievements. In 1982, INIFAP released the variety Flor de Mayo Bajio. It offers a shorter growth cycle (which decreases problems with rain at harvest), resistance to rust, and grain that cooks faster. The breeding program incorporates disease resistance from Colombian and Mexican germplasm into locally acceptable materials.

6.150 Problems. BCMV is the biggest challenge in irrigated production. Before this virus, irrigated yields averaged approximately 2 mt/ha; the average has dropped to 1.1-1.2 mt/ha. Although still susceptible to infection of plants in the field, two lines have been identified that do not transmit BCMV via seeds, and this resistance is being transferred into germplasm of the Bayo type.

6.151 Chicharrita, boroho, and storage pests of beans are serious problems. Rhizoctonia and fusarium fungi affect bean production in the Bajio, but researchers are indirectly selecting for resistance in programs with other objectives. Rust lowers yield under rainfed conditions, especially in July and August. Using resistant parents from Colombia and Mexico, two lines have been developed that appear immune to rusts in the Bajio. Common bacterial blight (Xanthomonas phaseoli and Pseudomonas phaseolicola) is also a danger.

6.152 Drought can be severe in Guanajuato; in years of low rainfall, reduced availability of irrigation water limits the area planted. Water quality is an issue in localized areas. A new project aims to incorporate into production cultivars genotypic variability for drought tolerance as well as for nitrogen fixation, N harvest index, and shorter cooking time.

6.153 Certified seed is planted only on 5-10 percent of the bean area in the Bajio because farmers want to limit expenses, PRONASE has a reputation for selling poor quality seeds, and it has also been slow to multiply seeds of new varieties. Researchers at the Celaya experiment station expect use of improved variety seed to increase now that the institute can sell seeds.[5]

6.154 Cropping practices in the Bajio should be studied. Since no research on fertilization has been done within the past 15 years, fertilization and nitrogen fixation by modern cultivars are poorly understood. Irrigation scheduling for beans has not been examined. Based on recommendations for wheat, the bean crop is irrigated from three to five times during the growth

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[5] Certified seed from PRONASE was used on 2-31 percent of the national bean area in 1977-1985.

cycle; this might be excessive, causing stress to the crop. Regional recommendations for planting date and density of planting have been elaborated, but information on local conditions is lacking.

6.155 In Celaya and nationally, most entomological research is on chemical insect control. Personnel and resources are needed for the study of integrated pest management on resistant varieties.

6.156 Lengthy gaps have occurred in the release of new, improved varieties, because of changes in breeders and delays in seed multiplication. The regional trial of the bean network is normally evaluated at five sites in Guanajuato; in 1989, it took place only in Celaya for lack of gasoline and vehicles.

6.157 Production systems in Jalisco. This state planted about 300,000 ha of beans in the 1960s, many of them intercropped with maize. By 1985 harvest area had shrunk to approximately 50,000 ha, of which 90 percent is rainfed. A maize sole crop has replaced maize/bean intercropping, due to higher profit, mechanization of maize production, and the use of maize herbicides detrimental to the bean crop. Migration to cities has resulted in fewer workers and greater labor costs. Such costs have a markedly negative effect on beans because the crop is more difficult to mechanize and commands a lower market price than other labor-intensive products (for example, horticultural crops).

6.158 Jalisco holds specific preferences in grain type--Azufrado, Flor de Mayo, Bayo, pinto, and garbancillo. Peruano, a variety from Nayarit and Sinaloa similar to an azufrado, commands the best market price and cooks well, but is not well-adapted to growing conditions in Jalisco.

6.159 Research systems. Bean breeding for northeast Jalisco began 15 years ago and research for other regions in 1980. There are now four experiment stations, working on yield potential, disease resistance, wide adaptation, and seed type, as well as on addressing the problem of herbicide residues from maize production and bean fertilization.

6.160 On-farm trials are used extensively in evaluating promising new genotypes, especially in Altos de Jalisco, where there is no experiment station. This area is the most humid research site and is used for disease-resistance screening. Candidate lines for release as varieties are planted in plots surrounding a plot of the farmer's variety, and the farmer manages the trial within his production system.

6.161 Research achievements. Breeding lines now yield more than double the landrace Tempranillo, common to the center and south of the state. These lines are entering evaluation in multilocation trials and are being used in additional crosses. Yields of 3-4 mt/ha under experimental conditions (rainfed) indicate that the center and south of the state have good potential for bean production.

6.162 Current problems. Drought is the most important limiting factor. Poor distribution of rainfall, steep slopes, and shallow soils (30-40 cm depth is common) with low organic content accentuate the problem. Dams constructed on a trial basis have worked well, but farmers lack financing for such projects. Hail, wind, and early frost are other weather-related stresses that affect bean production.

6.163 Anthracnose, angular leaf spot, rust, common bacterial blight, and root rots reduce bean yields in Jalisco by 20-80 percent, and breeding programs are underway to develop varieties for these conditions. Materials from CIAT, the U.S., and the Mexican germplasm bank are being used, as well as selections from 500-600 landraces collected in northeast Jalisco. A group of F7- and F8-generation materials is ready for multilocation trials.

6.164 Insects (the Mexican bean beetle) and low soil fertility also lower yields. Weed control is inadequate because of the shortage of field laborers. Technology has been developed for the use of fertilizer, insecticide, and herbicide, but these technologies are not yet accepted by farmers. Growers lack inputs, planters, and pesticide-application equipment, and no bank financing is available for intercropped beans.

6.165 Poor quality seeds and plant loss due to biotic and abiotic stresses commonly result in low plant populations. There is almost no certified seed available and the low market price for beans does not stimulate efforts by private seed companies. While improved bean varieties have been released in Jalisco, several have not entered production on a significant scale. The reasons for this include insufficient seeds, and time lag (the time required to release a variety is so long that the stress resistance incorporated into the material breaks down). Inferior cooking quality is also a cause of lack of acceptance, thus researchers have begun to consider analysis of cooking quality in bean selection programs.

6.166 Heavy labor requirements and the high cost of hand labor limit bean production. A cheaper, faster method of harvesting is much needed. Mechanization is very low in northeast Jalisco; only 15 percent of farmers have tractors. Production on farms larger than five ha is limited by the availability of machinery.

Chihuahua

6.167 Chihuahua has 24,700,000 hectares, of which 895,000 ha are in rainfed crops and 366,000 ha are in irrigated crops. The state is divided into three major climatic zones: the desert in the northeast, the mountains in the southwest (cattle and forest production), and the central zone (field crops). Agricultural research began in the Central Zone in 1957; and work on grain legumes is concentrated at the CIFAP experiment stations in Casas Grandes and Delicias, the principal rainfed and irrigated areas, respectively.

6.168 Rainfed. Chihuahas's rainfed conditions call for one crop per year, either in spring or in early summer. Maize is the principal crop, followed by beans, oats, wheat, sorghum, and potatoes. (In years such as 1989, when snowfall in the mountains was much below average, a smaller area is planted to maize, and beans become the chief crop.) About 200,000 ha of rainfed beans are planted, with an average yield of 300-500 kg/ha. Beans are generally sown on poor soils, highly susceptible to erosion. In 1989, 148,747 ha of beans were planted, which represented one quarter of the area in rainfed crops. With below normal moisture, yields averaged 235 kg/ha and Chihuahua imported beans (and maize) for the first time.

6.169 Irrigation. The command area of the Delicias station contains 161,000 ha of irrigated land and has the state's most intensive agricultural production. Delicias has a dry desert to dry semi-arid climate with 289-370 mm of annual rainfall (mean of 30 years data), while crop growth requirements range from 945 mm to 1,176 mm. Altitude ranges from 841 to 1,377 meters above sea level and the frost-free period (80 percent probability) is 193-255 days.

6.170 Two crops per year are normal in the irrigated areas. Wheat is the predominant crop in the fall/winter season, with secondary production of oats, pastures, horticultural crops, and safflower. Cotton is the most important spring/summer crop, with additional plantings of soybeans, sorghum, peanuts, maize, horticultural crops and beans. Low precipitation in 1988 and 1989 lowered reservoir levels to half of capacity and reduced the area planted to spring/summer crops.

6.171 Bean systems. In 1989, only 6,037 ha of beans were produced under irrigation (1.7 percent of the state's total irrigated area); normally, 7,000 ha are planted. Yields under irrigation average 1,500 kg/ha.

6.172 Ojo de Cabra is the predominant seed type produced (92 percent of planted area, followed by pinto beans (5 percent), and slight production of Bayo rata and namiquipa. Stover residues after harvest are important as animal feed in rainfed farming systems. Under irrigation, the production of soybeans and alfalfa reduces this need. Farmers normally plant carry over seed.

6.173 Research systems. Objectives in bean research are to develop better varieties for local conditions, to refine irrigation scheduling, and to multiply seed of improved varieties.

6.174 Research achievements. The optimum range of planting dates has been established and short-season varieties are available for late planting (Canario 101 and Bayomex). The variety Bayo Durango was released but later discovered to have no commercial value. In the pinto bean class, varieties Delicias 71 and Pinto Mexicano were released and other promising lines are in advanced evaluations. Varieties Ojo de Cabra 73 (1973) and Satevo (1983) were released and yielded 40 percent and 53 percent higher, respectively, than a traditional variety in research trials. Satevo has shown outstanding productivity under drought stress and is used as a drought-resistant control in CIAT international trials. However, the seed type does not fit into any existing commercial class and has no market potential unless consumer preferences change. Satevo is being used as a donor parent in breeding for drought resistance. Four Ojo de Cabra landraces have been selected for drought resistance and seed is being increased for evaluation in other parts of the state. The variety Pinto Nacional Morelos will be released in 1990.

6.175 Problems. The major factor limiting bean production in Chihuahua is lack of water; research has shown that each additional mm of water results in higher yield of 1.4 kg/ha. Common bacterial blight is the predominant disease in the state, which needs a source of varietal resistance. Conchuela and grasshoppers are the most common insect pests.

6.176 Low planting density and thus low plant populations under production conditions reduce yields. Producers generally fertilize with 20-30 kg/ha, less than the recommended rates, probably because of the high risk environment. Good quality commercial inoculum is available, but bean farmers are not familiar with the technology and yields are more stable with N fertilizer.

6.177 There is a strong consumer preference in Chihuahua and north Durango for the Ojo de Cabra seed type. Aside from a slight market in Mexico City, however, there is no outlet for excess production outside of the area of production.

Southern

6.178 Mexico's southern region plants approximately 300,000 hectares of beans, of which some 95 percent are of the small-seeded, black, opaque type. The region of south Tamaulipas, north

Veracruz, and east San Luis Potosi is characterized by high-technology, irrigated agriculture. Soybeans are an important crop and the climate is good for bean production in winter.

6.179 The southeast region does not produce enough beans to satisfy demand, thus it imports from Nayarit and Guatemala. Demand is high, especially in rural areas, where beans are eaten three times a day. A good government price program could increase the area planted to beans. The technology for raising bean production exists, but farmers need credit for production costs.

6.180 Problems. Since other crops (chilies and fruits) are more profitable, they are planted on the best soils, leaving beans the poorer soils. This has meant lower bean yields and has made beans a kind of subsistence crop, a problem compounded by farmer resistance to available technology.

6.181 Insect pests are not a major challenge. The principal diseases are BGMV and rust. The traditional bean variety, Jamapa, is susceptible to BGMV; the variety Negro Huasteco 81, released in 1981, is resistant to BGMV, rust, and Empoasca leafhoppers and is an erect plant with pods higher off the ground. Negro Huasteco 81 yields an average 1.2 mt/ha, with production of 1.5 mt/ha reported under good conditions. The yield of Jamapa is similar under low stress conditions but falls off sharply with pressure from BGMV and other pests.

6.182 Beans. Chiapas grew approximately 88,000 ha of beans in 1988, mostly in the central valley between 350 and 1,500 m.a.s.l. There are three production systems: irrigated before the rainy season, rainfed during the rainy season, and residual after the rainy season. Most of the bean production is by ejidatarios on 1-1.5 ha farms, and during the last 10 years, productivity has averaged slightly over 500 kg/ha. Of the beans produced, 11 percent goes for seed, 18 percent for food, and 71 percent for sale.

6.183 Problems. Factors limiting bean production in Chiapas include diseases (mainly BGMV), poor soil fertility, and water (too much during the rainy season, too little at other times). Although beans have long been an important crop in the coastal region, current production has fallen to almost nothing because of problems with BGMV.

6.184 There has been little success in widening the use of new varieties. Available resources limit on-farm demonstration plots and the seed for new varieties is in short supply. Trained personnel and equipment are needed in seed production and conditioning, and better storage facilities are required.

6.185 Research achievements. The varieties Negro Chiapas and Negro Huasteco have some resistance to BGMV, but control of white flies is still needed. On the coast, three BGMV-resistant lines from CIAT were evaluated under on-farm conditions in the 1988-89 winter season, and yields ranged from 900 to 1,300 kg/ha with residual moisture. This year a Chiapas farmer planted several ha of one of these lines, DOR 364, as well as a new variety from Guatemala. In an adjacent field, INIFAP researchers are testing 15 promising lines from Guatemala and CIAT for adaptation, yield, and resistance to BGMV.

2. Soybeans

Northwest

6.186 Of Mexico's 400,000 ha of soybeans, 80 percent grow under irrigation in Sonora and Sinaloa. The entire crop is for the domestic edible oil market and for animal feed.

6.187 In Sonora's Yaqui Valley the predominant cropping system is wheat (November to April) and soybeans (May to October). Soybean planting varies from 15 April to 15 June. Maturity groups V to VIII are planted, but group VI predominates. All are determinate types. The growth cycle is from 120 to 130 days until maturity and approximately 140 days to harvest. Soybean seed for planting in the northwest comes mainly from Chihuahua.

6.188 Soybean yields in Sonora average 3.0 mt/ha (the national average is 2.0) and have been stable for the past five years. Although rhizobial inoculum (produced in Jalisco) is used on only a small portion of the soybean area, no nitrogen fertilizer is applied. Residual P from fertilization of the wheat crop is sufficient for the soybean crop and the soil is naturally high in K.

6.189 Between the areas of Los Mochis and Culiacan, Sinaloa, 16,000- 246,000 ha of soybeans are planted, depending upon the availability of irrigation water. Typical production is as a summer crop in rotation with wheat. Soybeans are not produced in the south of Sinaloa because there is no irrigation. Productivity is stable at 2.0-2.2 mt/ha.

6.190 Research systems. Soybean research began in the Yaqui Valley in 1959. The regional center for soybean breeding is at CIANA, which also addresses the problem of iron chlorosis. Culiacan is a subcenter, with labs for soil fertility, pathology, and entomology. One researcher works on irrigation technology; and two entomologists spend only about one fourth of their time on soybeans. There is a little pathology work on soybeans.

6.191 Research achievements. A production package of technology for soybeans has been developed for Sonora. Many soybean varieties have been released in the northwest, including Cajeme (CIANA, 1970), Tetabiate (CIANA, 1971), Sanalona (Los Mochis, 1976), Culiacan (Los Mochis, 1978), Tamazula 80 and Rosales 80 (Los Mochis, 1980), Mayo 80 and Sonora 80 (CIANA, 1980), Precoz VF 82 (Los Mochis, 1982), Batuc 86 and Suaqui 86 (CIANA, 1986), and Harbar 88 (CIANA, 1988). Varieties Davis and Bragg (USA) are also popular. At Culiacan, two breeding lines have been selected that consistently outyield Tamazula 80 (developed at Culiacan).

6.192 Current problems. Problems include availability and quality (salinity) of irrigation water, and frost, insects, and diseases. Researchers at CIANA believe that grain legume production in Sonora will probably not increase because of inadequate water; heavy use for irrigation is depleting the aquifers. Prompted by this reduction in water reserves and by the cost of irrigation, CIANA researchers have begun preliminary investigations on crop water use efficiency. Economic return per m^3 of irrigation water shows that horticultural crops are generally more efficient than cereals and grain legumes; wheat is between chickpea and soybean.

6.193 Because of the delays in field preparation after wheat harvest, approximately 80 percent of Sonora's soybean crop is planted in June or later. Since the soybean varieties are photoperiod-sensitive, June planting results in a shorter vegetative cycle, shorter height, fewer nodes, and reduced yield. April-May planting gives 2.5-3.0 mt/ha yields; June or July planting reduces yields to 1.5-2.0 mt/ha. Shorter season that would be better adapted to this rotation system are needed, but the variability of available germplasm is limited and lateness dominates. Research is also called for on management practices to reduce the time between wheat harvest and soybean planting.

6.194 Relatively high insecticide applications are used on soybeans in Sonora, and insect resistance has developed as a consequence of using the same insecticides for a decade. Chlorinated insecticides leave a residue in the seeds, and other insecticide options are of the same chemical family as that currently used, so the same resistance applies. The current staff must work on an immediate solution to the problem and concentrate on studying insecticide resistance. Additional researchers are needed to work in alternative areas of insect control, such as biological control and cultural practices to reduce populations or avoid times of high pressure. The program of breeding varieties for resistance to insects is general and shallow.

6.195 Macrofomina phaseole is the worst disease of Sonora's soybeans, but nematodes are also a problem. Since there is no soybean pathologist, diseases are not well quantified.

6.196 Sinaloa problems. The photoperiod sensitivity of soybeans restricts the time for planting without reducing yields. Problems include late sowing; poor pest control for lack of knowledge, technology, or cash; erratic fertilizer use; localized salinity problems; high pH (7.5-8.3); and slow acceptance of new varieties due to lack of available seeds. Early planting results in less rain at harvest but increased incidence of pests; late planting leads to reduced pest pressure but a higher probability of rain at harvest.

6.197 The climatic conditions of the normal cropping cycle result in poor quality seeds. INIFAP researchers are interested in raising winter soybean seed production in the south of the state (less danger of frost), but to date only a small area has been planted. The technology exists but yields are low (1.0-1.3 mt/ha) due to photoperiod sensitivity. There is no premium for seed production, so soybean for seed does not compete well with other winter crops. Producers are not accustomed to planting winter soybeans and there is a lack of extension effort to introduce the practice. As a result, almost all soybean seeds for the region are imported from Chihuahua and the United States.

6.198 The biggest problem in soybean production is the high cost of production (expensive inputs and machinery, low credit availability). Culiacan is working on reducing costs by cutting tillage operations, seeding rates, and fertilizer use. Some technology has been developed to lower production costs.

6.199 Two species of leaf-feeding insects attack soybeans in the Culiacan area. Resistant lines exist and a research program has started to incorporate this resistance into commercial cultivars. The availability of soybean seed from Chihuahua and the United States also limits production in Sinaloa. Research has been in progress for 15 years at Culiacan in search of varieties that yield well in both summer (industrial production) and inter (seed production). Since winter seed production competes with wheat, beans, and horticult. crops, yields must be increased to make soybean more competitive. Currently, up to 1,000 ha (but usually fewer) of soybean seed are produced in winter using technology developed at Culiacan.

El Bajio

6.200 In the Bajio, the normal crop rotation involves planting sorghum between March and May and harvesting in November-December; wheat is then planted in December. Although soybeans are not produced commercially in Guanajuato, INIFAP Celaya and an organization of private seed growers (AALPESS) are investigating the crop as a possible substitute for sorghum in the rotation. Since the growth cycle of soybeans is from May to September, this change offers the advantage of more time to prepare fields for planting wheat in December. Varieties Bragg (US) and Cajeme (Sonora) have produced 2.5 mt/ha under experimental conditions with irrigation and an optimum planting date.

6.201 Jalisco. Some INIFAP research has been done on soybeans in Jalisco, and the crop appears reasonably well-adapted. Lack of both a tradition of growing soybeans and appropriate mechanization limit adoption, but the major deterrent is low market price relative to production costs.

6.202 Problems in the Bajio. Soybean seeds are not produced in the Bajio region and must be imported from Chihuahua. The experience to date is that seed quality is bad by the time it arrives in Celaya. Also, experimental plots were inoculated with Bradyrhizobium but did not nodulate, so a source of good quality inoculum may be needed. In addition, the region's farmers are not familiar with soybeans, thus a strong extension effort will be needed to introduce the crop.

Chihuahua

6.203 Research. Agricultural research began in the central zone of Chihuahua in 1957. Grain legume research is concentrated at the experiment stations in Casas Grandes and in Delicias, the principal rainfed and irrigated areas, respectively. In 1960, commercial soybean yields with available varieties averaged 360 kg/ha.

6.204 Soybean research at the INIFAP Delicias Experiment Station began in 1962 to seek an alternate crop for cotton. Early work was concentrated on breeding and agronomic practices. The technologies of optimum planting dates and fertilization (the use of 30 kg N/ha in combination with Bradyrhizobium inoculant from Guadalajara) have been established for mechanized production as a summer crop in rotation with wheat.

6.205 With the release of the U.S. cultivar Davis in Chihuahua in 1967, yields rose to 2,500 kg/ha. Seed production began in 1971 with the varieties Davis and Cajeme, and by 1973, 47 percent of the State's soybean area was devoted to seed production, mainly for sale in Sonora and Sinaloa. Since 1983 Chihuahua has ranked first nationally in soybean seed production. In 1989, 95 percent of its soybean area produced seed (the remaining 5 percent was industrial production only because it was substandard for seed use). Average yields for the past 20 years have remained fairly static between 2.0 and 2.7 mt/ha, due to the continued predominance of the varieties Cajeme, Bragg, and Davis.

6.206 Current problems. Iron chlorosis and late planting due to rotation conflicts with wheat are the principal factors limiting soybean yield in Chihuahua. Current research emphasizes breeding and selection of new lines with higher yields and better resistance to iron chlorosis; promising materials have been identified and are being evaluated in elite adaptation trials in Chihuahua, Sonora, and Sinaloa. On-farm evaluation and demonstration plots are installed to raise farmer interest in planting newer varieties that yield better than Cajeme. However, since all of the area sown to soybeans is intended for Sonora and Sinaloa, the varieties planted are controlled by demand in the northwest. Research in Chihuahua should thus be focused on management practices to increase yield of the varieties grown in the northwest, rather than on developing new varieties that have no market.

Southern

6.207 Soybeans are an important crop in the region of south Tamaulipas, north Veracruz, and east San Luis Potosi, which is characterized by high-technology, irrigated agriculture. In the south of Tamaulipas, soybeans are also grown under rainfed conditions as a summer crop in rotation with safflower or sorghum. There is some winter production under irrigation. Previously, 100,000 ha were planted to soybeans, but recently the area has fallen to 40,000 ha due to low market price and cheaper imports. Yields average only 1.0 mt/ha, mainly attributable to lack of planting at the proper time. Excess or scarcity of rain often results in planting later than the established optimum time (15 June-15 July), which usually leads to insufficient rain during the pod-filling phase of growth.

6.208 Popular soybean varieties in the south include Tapachula 86 (released by INIFAP), Jupiter (U.S.), Santa Rosa, and several other Brazilian varieties. In the south of Tamaulipas, private seed companies sell almost all the soybean seed planted, but due to low market price, private industries there do not work much with soybeans. Seed quality deteriorates quickly in the hot, humid climate, and new seeds are needed each season. The majority of seed comes from Brazil and the United States. INIFAP research is focusing on both pre- and post-harvest causes of low seed quality.

6.209 In the state of Chiapas the production of soybeans for industrial use is concentrated in the humid tropical coastal region. Approximately 27,000 ha are grown as a summer rainfed crop in rotation with sesame, maize, melons, or sorghum; the crop is normally planted between June and August and harvested in October or November. Yields average 2.2 mt/ha, but individual farm yields reach 3.5 mt/ha. It is estimated that the northeastern, coastal, and central valley regions of the state contain 200,000 ha appropriate for industrial soybean production.

6.210 Research systems at Tapachula. Work at Tapachula is concentrated on evaluating lines from programs outside of Mexico. There is no true breeding work, but several new lines were tested and found to have good seed quality and adaptation, but low yields. University of Florida materials are generally better and one line was released in 1986 as the variety Tapachula 86 (Aleman et al. 1989). In multilocation verification trials, Tapachula 86 yielded 15 percent better than current production cultivars. In 1986, some 200 Brazilian lines were evaluated. Some of these perform very well in Chiapas, and researchers at the Rosario Izapa Experiment Station want to release them as varieties. Currently, the variety UFV 1 (Brazil) is the most popular in production. Other commercial varieties include: Jupiter (U.S.), Tapachula 86, Santa Rosa (Brazil), Cristalina (Brazil), and Hartz 9190 (U.S.).

6.211 INIFAP scientists have developed agronomic production practices (improved varieties, time and density of planting, and chemical pest control). A program has been underway for two years to produce soybean seed by planting with winter irrigation. In the 1989-90 season, the area dedicated to soybean seed production grew to 800 ha, which should have supplied 30 percent of the state's seed needs for the 1990 summer crop. An area of 16,500 ha has potential for winter soybean seed production, and this could be enough to satisfy the needs of the entire region.

6.212 Problems: Chiapas. The factor most limiting to soybean production in Chiapas is seed availability. High temperatures and relative humidity result in poor quality seed at harvest and rapid loss of germination and vigor after harvest, precluding the planting of seed from last year's crop. The majority of seed is imported from Brazil and the United States. Although there is sufficient time for field preparation between the harvest of the winter crop and the optimum planting time for soybeans, frequent delays in the arrival of seeds and insufficient planting equipment often result in sowing soybeans in August. Research has shown that delaying planting from June to August cuts yields from 3.0-3.5 mt/ha to 0-1.0 mt/ha. This yield reduction has been attributed to photoperiod sensitivity of soybeans and greater attack by insects. Harvest losses are also prompted by the lack of sufficient combines for timely work, which results in more pod-shattering and weed growth.

6.213 The growing program to produce locally seeds of Tapachula 86 and Cristalina during winter may help reduce the problem of late planting, though yields will be low under irrigation. Rainfed seed production in winter is not viable because of slower plant growth and greater risk. Controlled environment storage facilities are required for conservation of foundation and registered seeds. Although seeds produced in winter come out of the field in April, considerable loss of germination and vigor can occur before planting in June or July (significant loss occurs within 15-20 days after harvest for some varieties). Controlled storage chambers for certified seed would reduce yield loss due to poor quality seed, enable the state to send seed to other states in the region, and allow farmers to store industrial-grade seed until prices improve. Earlier planting (May) of the summer crop is not a good option, since there is greater probability of rain at harvest. Adequate ambient conditions for seed storage exist in the mountains, but the cost of transportation is prohibitive.

6.214 Weeds and insects (principally white flies) are important problems in soybean production. Although technology for chemical control has been developed, its use raises production costs. Research on biological insect control is in progress but has not yet developed a technology for use under production conditions. Anthracnose and root rot fungi are the most serious diseases. The technology of inoculation with rhizobia is common, but poor inoculant management and the lack of better bacterial strains combined with low soil fertility sometimes result in severe nitrogen deficiencies and subsequent yield loss.

Conclusions on Grain Legume Research

6.215 All grain legumes. Major emphasis has been given to developing greater genetic potential and resistance to environmental stress. The balance between rainfed and irrigated systems seems to have been appropriate. Varieties are being released and production technologies developed and refined. Although bean yields have not changed since 1970 (Acosta 1988a and 1988b), this is due to lack of adoption of research products and to the fact that more profitable crops are pushing bean production into less favorable areas.

6.216 Research has emphasized breeding for disease resistance and yield in areas with more favorable growing conditions and better infrastructure, as these areas have offered the highest potential.

Table 6.9. Bean Research Priorities

Problems	Regions	Techniques
National bean priorities are grain color, disease resistance, crop cycles	National	Crop cycles, Grain color
Bean drought resistance	National	Breeding
BGMV, BCMV, BSMV, and other diseases serious in Sonora and Sinaloa	Sonora Sinaloa	Breed for resistance
Irrigated bean research for disease resistance, cycle in Bajio	Bajio	Breeding, Irrigation
Rainfed bean research on drought, rust, and BGMV resistance, bean quality, and N Fixation in Bajio	Bajio	Breeding Rainfed
Bean constraints are dorado mosaic, whitefly, soils in Cotaxtla	South	Breeding, crop agron

Source: Mission interviews

Although this work must continue, additional emphasis is needed in the physiology of yield and of stress, integrated pest management, and cropping practices. More attention should also be given to the more marginal production areas, since competition from other crops is less intense there.

6.217 Beans. The balance between bean researchers and the geographic areas of bean production is not uniform (Acosta 1988b). The rainfed production area of the north (Aguascalientes, Zacatecas, and Durango) contains more than half of the national area planted to beans, but few bean researchers. The preponderance of high-risk production in less-favorable environments dictates more research emphasis in these areas. In addition to agronomic studies, this research should include selection of breeding lines under typical production stresses.

6.218 Drought is the factor that most limits bean production and it should continue to receive the highest research priority. The drought resistance of the variety Satevo, released in Chihuahua, needs to be incorporated into commercially acceptable seed types, and the mechanisms of Satevo's resistance should be thoroughly studied. This is one area where genetic engineering could have a significant impact. Additional emphasis should be placed on evaluating wild beans and landraces from germplasm banks to increase drought resistance and to broaden the genetic base of cultivated varieties. Additional research is needed on water management to reduce drought stress by increasing water supply.

6.219 Beans in multiple cropping systems have received little research attention. This lack of emphasis seems justified in the areas this Mission visited, but before making a recommendation, we would need more information on the national importance of mixed cropping.

6.220 One sector that deserves more attention is the producing areas with little or no mechanization, for example, those in the northeast of Jalisco and the center of Chiapas. Increasing production is more difficult under these conditions and the benefits are not as great on a national level. Work should emphasize technologies, including rudimentary mechanization, that are compatible and viable within the existing farming systems. The lack of a total mechanized harvest is one of the biggest obstacles to increasing bean production. Harvest labor costs, the lack of laborers, and losses due to untimely operations reduce profits and, consequently, the area planted to beans. More research is needed to mechanize the bean harvest, by modifying the plant and by developing appropriate machinery.

6.221 With insufficient funds and personnel, it is not easy to expand research into other geographical and disciplinary areas. One way to accomplish this would be to establish regional research centers, as proposed by Acosta (1988b). Each center could concentrate on general problems and those unique to the region. Currently, INIFAP maintains many experiment stations, each staffed with a few researchers (mainly breeders). The majority of these experiment stations would be just as functional if staffed by an agronomist to evaluate breeding lines and production technologies generated by the appropriate regional center. The development of germplasm and technology would be done at the regional centers by multidisciplinary teams. Regional organization would reduce duplication of effort and provide the critical mass necessary for significant progress. Redistribution of researchers to regional centers would eliminate situations such as a bean breeder, but not breeding work, in Mazatlan.

6.222 Another option is to increase bean production in the south, where rainfall is more dependable, and to transport the grain to higher-risk areas for consumption. Since local preferences for seed types are very specific, this would require development of varieties of seed types with resistance to the stresses (diseases, fertility, and so on) of a more humid environment.

6.223 Regional preferences in consumption of specific seed types greatly complicate the goal of self-sufficiency in bean production. In years of favorable growing conditions, production is relatively high throughout a region, and production exceeds local demand. Since preferences are generally on a regional basis, marketing the excess is difficult. (The notable exception is the case of small-seeded, opaque, black beans, consumed in Brazil, Guatemala, Cuba, Venezuela, and other countries; more emphasis could be placed on production of this type in Mexico). In years of shortfall, it is difficult to import the preferred seed type and consumption falls. Changing these traditional habits and preferences is difficult and is generally not considered in discussions concerning bean production and consumption. However, many people would not have believed that Mexican consumption of yellow-corn tortillas was feasible.

6.224 The gap between research and the farmer is not being adequately filled. In most regions, seed supply limits the use of improved varieties. Adoption of new varieties and technologies is also restricted by the lack of an effective extension service. Low salaries and personnel reductions have cut research staff to a bare minimum and the effect on extension has been more pronounced. Extensionists are essentially inoperative for lack of transportation and resources to transfer technology, and the level of technical expertise is dropping as qualified people leave for better jobs.

C. Tropical Livestock [6]

Introduction

6.225 Livestock are a major element of Mexico's agricultural economy. Livestock production in 1985 had a value of Mex$1,374.7 billion, or nearly three percent of GDP. The share of animal production in animal and crop output value was 31-37 percent from 1955 to 1985.

6.226 Animals furnish an important part of protein consumption. In 1970 the share of animal products (meat, poultry, pork, eggs, and milk) in total protein consumption was about 30 percent, a fraction that changed little between 1970 and 1984. The quantity of animal protein consumed in 1985 was about 30 grams per capita per day, up from 24 gm in 1970. As the amount of non-animal protein (grains, legumes, sugar, fruits, vegetables, and edible oils) has risen steadily since 1950, quantity of animal protein consumed has likely risen as well.

6.227 Little of Mexico's animal production and consumption enters international trade. From 1972 to 1985, the country exported about 10 percent of beef production and imported less than 5 percent of its pork and less than 15 percent of its milk. Mexico is the largest Latin American importer of milk products per capita, but it remains about 85-90 percent self-sufficient in milk and basically self-sufficient in meat.

6.228 Animal production is diversified. The most recent estimates of shares by commodity in the value of livestock production were beef, 52 percent; pork, 27 percent; poultry, 17 percent; other, less than 5 percent (Schiavo 1983). Of the value of cattle production, milk contributed about 38 percent, beef 53 percent, and hides, skins, and viscera made up the rest.

6.229 Despite the diversity of animal products and production systems, this chapter concentrates on cattle production in the tropics, for several reasons. First, problems of research and technology transfer have been better solved in the arid and temperate zones. Much technology--crossbred dairy cattle, irrigated forages, concentrated feeds--has been adopted by producers in the drier and cooler climates. Second, the tropics offer more potential for extensive livestock development because population density is lower--thus land competition between crops and animals is less acute than in more densely populated areas. Last, productivity in the tropics is so low compared with that in the arid and temperate zones that significant gains can be foreseen from research and extension in the tropics.

6.230 The chapter does not discuss pork, poultry, or small ruminant (sheep and goat) production. We consider that the research issues in pork and poultry are less difficult than in cattle, and that existing technologies are adequate; the problems are economic and not technical. With respect to small ruminants, their share of output is very small, and they would, in any event, benefit from forage techniques targeted primarily at cattle.

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[6] This section is derived from the work of Osvaldo Paladines (consultant) which is included as Annex 4 of the Technical Files for this Report.

1. Livestock Production Systems

Cattle Production In Mexico

6.231 Mexico has three principal cattle production systems (National Institute for Statistics, Geography and Information--INEGI/SARH, Table 2.1.15)--the northern arid and semiarid, the central temperate, and the tropical. Each has distinctive stocking rates, breeds, feed systems, and products.

6.232 Cattle stocking rates (in ha per animal) differ markedly among systems, as follows:

arid and semiarid	16-55
dry tropical	1-4
humid tropical	0.5-21

6.233 Arid and semiarid. These are mainly in the states of Sonora, Chihuahua, Coahuila, and Durango. The main product is young cattle for export to the United States. Feed is natural pastures, with some production of sown forages, such as alfalfa, and forage maize or sorghum. Beef breeds, such as Angus and Brahman, dominate. Artificial insemination (AI) is practiced on less than 15 percent of the herd. Productivity per adult animal is low, with carcass yields below 50 percent and carcass weight between 150 and 170 kg (Schiavo 1983).

6.234 Temperate. These are the states of Jalisco, Mexico, Michoacan, and Puebla, which have much of the country's dairy production. The principal sown forage, alfalfa, grows here, generally with irrigation. Specialized dairy farms are highly developed and use Holsteins, sown forages, and purchased feed, and production can surpass 10,000 liters of milk/ha/year. INIFAP has developed techniques for these farms, using irrigation, N-fertilizer with ryegrass (Lolium multiflorum) for winter grazing, and improved Bermuda grass (Cynodon dactylon) for summer grazing.

6.235 The tropics. This is notably Veracruz, Tabasco, and Chiapas, where the principal systems are beef and dual-purpose.[7] Much of the meat for the domestic market comes from the south. Cattle production is most extensive in the drier areas where cattle depend upon sparse native pastures of low primary production. In the dry tropics, sown forages occupy only 4 percent of agricultural area (natural pastures, sown pastures, and crops) compared to 44 percent in the humid tropics. Among dry tropics farmers, 84 percent sell weaned calves, 15 percent sell them as feeders, and only 1 percent do fattening; milking of the beef Zebu cows is a generalized practice. In the humid tropics, the predominant system is dual purpose cattle; 70 percent of producers milk their cows in Veracruz, and a lower proportion in Tabasco and Chiapas.

6.236 The humid tropics with their more regularly distributed forage production have higher productivity than the dry tropics (Table 6.10), but productivity per animal is still much lower than in temperate areas. One study (University of Chapingo and PRODERITH 1989) found these mean indicators of cattle productivity:

[7] One study classifies parts of Sonora and Sinaloa states in the dry tropics (Peralta and Ramos 1987).

(a) herd structure:

bulls	2 %
dams	36 %
growing heifers	19 %
growing steers	25 %
calves	18 %

(b) productivity:

age of weaning	9 months
age at slaughter (on pasture)	45 months
extraction rate	14 %
average milk production	1.2 liters/day

6.237 Milk production in the tropics. One of the purposes of livestock research in Mexico has been to improve tropical dairy production. Broadly, there are three main sources of milk (Table 6.11): specialized dairy farms, mostly found in the cool mountain irrigated region; family dairy farms throughout the country; and dual-purpose production in the tropics. Specialized farms produce about 28 percent of the national milk supply; family farms, 50 percent; and dual-purpose, 22 percent (Munoz et al 1989, p. 5). While nearly 30 percent of the national milk supply comes from dual-purpose animals of the tropics, productivity per animal there is lower.

Table 6.10. Cattle Production In The Mexican Tropics

Parameter	Dry Tropics	Humid Tropics
Stocking Rate, Animal Units/Ha	.3	.7
Steer Weight At 36 Months	260.0	300.0
Age at First Conception, Months	36.0	32.0
Calving Interval, Months	22.0	17.0
Weaning, %	45.0	58.0
Animal Weight Gain (Kg):		
Per Animal/Year	60.0	75.0
Per Hectare/Year	15.0	42.0

	Pastures			Total	Cattle	Production of	
	Natural	Cultivated	Crops	Area	Numbers	Meat	Milk
	(-------------thousand hectares---------)				(thousands)	(thousand mt)	
Dry tropics							
Sinaloa	1,369	2	427	1,798	850	32	80
Nayarit	1,159	4	346	1,509	807	24	80
Jalisco	708	37	99	843	236	9	78
Colima	220	13	179	412	267	8	37
Michoacan	1,653	4	226	1,883	643	19	133
Guerrero	1,365	3	370	1,738	777	25	58
Oaxaca	1,500	12	214	1,726	598	16	61
Chiapas	274	182	493	949	473	15	47
Tamaulipas	607	50	287	944	550	18	43
Veracruz	347	368	227	942	614	24	80
Yucatan	148	48	240	436	284	6	11
	9,350	723	3,108	13,180	6,099	196	708
Wet tropics							
Veracruz	1,040	2,890	1,290	5,220	3,572	137	490
Tabasco	311	1,189	231	1,731	592	19	59
Oaxaca	76	95	26	197	1,719	68	143
Chiapas	929	658	747	2,334	256	7	26
Campeche	335	336	445	1,116	2,886	85	270
Quintana Roo	63	110	206	379	452	10	43
Yucatan	301	334	477	1,112	54	1	4
San Luis Potosi	654	168	160	982	597	14	19
	3,709	5,780	3,582	13,071	10,128	341	1,054

Source: Peralta and Ramos, 1989

Table 6.11. Systems Of Milk Supply In Mexico, 1985

System	Number Of Farms	Herd Size, Number	Production per Lactation (kg of milk)	Contribution To Total (%)
Specialized Dairy	1,850	230	5,000	0.28
Family Farm	100,000	15	2,500	0.50
Dual Purpose	120,000	20	700	0.22

Source: FIRA (1988)

6.238 The causes of lower productivity per animal in the tropics are several. One is the higher percentage of Zebu blood in the dairy herd, giving lower yields per animal than the temperate breeds. Forage quality is lower. Depending upon the price of milk, there are proncunced shifts in tropical milk supply; when the price is high the farmer sells more milk, and when it is low he gives more to the calf.

6.239 Use of improved techniques. Tropical farms vary widely in size and type of operation. One study showed a range of farm sizes from 23 ha to 1,370 ha, around a mean of 83 ha (Munoz et al 1989). The distribution of improved techniques was as follows:

	Percentage of Producers
Area fertilized (mineral or organic)	3%
No paddock division	37%
Uses rotational grazing	60%
Has used improved pastures	54%
Uses mineral mixtures	22%
Uses salt	57%
Uses supplements (by-products, molasses, urea)	24%

Agroecology Of The Mexican Tropics

6.240 Area. The tropics cover nearly 50 million ha or 25 percent of the national territory. The area is divided between dry and wet tropics (main map 1), with estimated areas of 23.7 and 25.7 million ha, respectively. The dry tropics follow a strip down the west coast and another on the northern coast at Yucatan; there are dry tropics in the states of Sinaloa, Nayarit, Jalisco, Colima, Michoacan, Guerrero, Oaxaca, Chiapas, Tamaulipas, Veracruz and Yucatan. Nayarit and Colima belong entirely to the dry tropics, while the rest have dry and wet. The largest wet tropical states are Veracruz, Campeche, Quintana Roo, and Chiapas, with lesser areas in Yucatan, Tabasco, Oaxaca, and San Luis Potosi. All of Tabasco, Quintana Roo, and Campeche are in the humid tropics.

6.241 Soils. Varied origins and prolonged weathering have produced eight major soil types in the tropics (Table 6.12). The innately fertile Luvisols and Vertisols cover 48 percent of the tropics. Other soils are infertile because of weathering and use. Phosphorous is low to very low in most soils, particularly in Nitosols and Acrisols which also have high aluminum saturation and low pH.

Very infertile soils form less than 15 percent of the Mexican tropics. The predominance of good fertility soils is reflected in the adaptation of pasture species which require these types of conditions.

Table 6.12. Principal Soil Types of the Mexican Tropics (Km²)

Dry Wet Type	Tropics	Tropics	Total	Percentage
Cambisol	50,214	71,409	121,623	24.6
Luvisol	44,299	76,890	121,189	24.5
Vertisol	66,664	46,919	113,583	22.9
Rendzina	3,913	48,315	52,228	10.6
Acrisol	13,904	29,320	43,224	8.7
Nitosol	24,859	3,006	27,865	5.6
Gleysol	0	11,225	11,225	2.3
Litosol	3,800	0	3,800	0.8
Total	207,653	287,084	494,737	

Source: Peralta and Ramos (1987).

6.242 Climate. Mexico uses the Kopen system climate classification, based on temperature and rainfall distributions. The main climates are of Type A (hot and humid) with small areas of Type B (dry) climates. The predominant types are the hot dry (Awo) with a dry season of more than seven months and summer rains. Most of the Pacific coast falls under this climate from Sinaloa to the center of the Isthmus, with a stretch also in Chiapas. On the Gulf Coast the same climate is found in the south of Tamaulipas, and in the centers of Veracruz and Yucatan. The other important climates are the hot and humid with summer rains (Am) and hot and subhumid (Aw2). In both, rainfall is above 1,200 mm/year, most of which falls between June and October. These climates predominate in Veracruz, Tabasco, North of Chiapas, Campeche, and Quintana Roo. An additional element on the Gulf Coast is cold winter north winds.

2. Livestock Research Systems

INIFAP's Livestock Research

6.243 The perception that research had been conducted in a disjointed way stimulated creation of INIFAP in 1985 in crops, livestock, and forestry. Its structure by state (CIFAP) and national disciplinary centers (CENIDs) was intended to unite agricultural research efforts. Initially, the Center for Research in Veterinary Medicine (CIMEVET) was divided into two: the Center of Animal Parasitology Jiutepec, Morelos, and the Center for Microbiology at Palo Alto. Twenty two INIP Research Centers now depend on the CIFAPs. INIFAP today has three national centers (CENIDs)--microbiology, parasitology, and animal physiology--and nine livestock research networks--beef, dairy, sheep, poultry, swine, apiculture, goats, forages, and epidemiology (Table 6.13). In percentages, 300 trained scientists specialize thus: beef (33), dairy (23), forages (12), swine and poultry (11), sheep (8), epidemiology (3), and other fields (10).

Table 6.13. Universitv Graduates In Animal Production In INIFAP, 1989

State or CENID	Beef	Dairy	Sheep	Poultry	Swine	Apiculture	Forages a/	Goats	Epidemiology	Total	Total PhDs
D.F.			1							1	
Mexico	4	4		2					1	11	
Zacatecas	1									1	
Nayarit	14	4	2							20	
Puebla	8	3	2							13	
Coahuila	1									1	
Jalisco	7	7	2		1					17	1
Chihuahua	6	2							1	9	1
Michoacan		1	1	1	2					5	
Sonora	10								1	11	
Chiapas	1	1					5			7	
Campeche	2						2			4	
Panuco	7	2					3			12	
Quintana Roo	2	3	1				3			9	
Tabasco	2	7			1		5			15	
Yucatan	3	2	4		1	3	8			21	1
Veracruz	4	16	1	2	3	1	1		1	29	
Guerrero	1	2					3	1		7	
Oaxaca		2					5			7	
Baja California Norte										0	1
Tlaxcala								1		1	
Nuevo Leon									1	1	
Ajuchitlan				1	1			3	1	6	1
Palo Alto	19	8	5	3	13				2	50	11
Jiutepec	6	5	3	2						16	2
Morelos									1	1	
Queretaro	1		2	1						4	3
Total	99	69	24	12	22	4	35	5	9	279	21

a/ Only tropical areas.

Source: Listing provided by INIFAP.

6.244 Distribution of staff by networks. Table 6.13 summarizes INIFAP personnel by research station, network, and training. Research in animal production takes place at 37 experimental fields and in all 3 CENIDs. Beef cattle work is done at 23 stations and in CENID-Microbiology and CENID-Parasitology; 12 of the stations are in the tropics. One hundred and four researchers are involved in beef production, of which 26 percent are in the CENIDs and 19 percent in tropical experiment stations.[8]

6.245 INIFAP dairy production research is conducted at 22 stations (10 in the tropics) and at the CENIDs for Microbiology and for Parasitology. There are 75 scientists, of whom the CENIDs list 22 percent and tropical areas 42 percent. Of the staff in tropics, 23 people have Lic degrees and 8 have MSc.

[8] There is little work in swine and even less in poultry.

6.246 Sheep research is done at 10 research stations (4 in the tropics) and at the CENIDs for Microbiology and for Parasitology. Twenty eight researchers work with sheep, 36 percent in the CENIDs, and 21 percent in the tropics; of tropical staff, 4 have Lic degrees and 2 MSc. Swine production takes place at 6 stations, and at the CENIDs-Microbiology and Physiology; 3 stations are in the tropics. Of 28 research people, 61 percent are at the CENIDs and 6 percent in the tropics (5 persons, 3 Lic and 2 MSc). Poultry work is conducted at 4 stations, the 3 CENIDs, and a single tropical station. Thirteen researchers form this network 54 percent in the CENIDs, and 2 in the tropics.

6.247 Pasture researchers, only for the tropics, number 33 scientists, 25 with Lic degrees and 8 with MSc degrees. This is one of the better-equipped animal production networks, and its program works closely with CIAT's regional germplasm network.

6.248 Distribution of staff by state. State distribution is uneven; for example, seven states have only one animal production scientist each. The tropical states list 35.3 percent of the scientists, nontropical states 35.7 percent and the CENIDs 29 percent. In the tropics, most scientists are in Veracruz (27.4 percent), Yucatan (21.7 percent), Tabasco (14.2 percent) and Panuco (11.3 percent). Other states have less than 10 percent each, and Campeche has the fewest (3.8 percent). The concentration of scientists in Veracruz, Yucatan and Tabasco is consistent with the distribution of livestock.

6.249 Distribution by theme. Research is concentrated in dairy, beef, and forages. Dairy research (largely dual-purpose production); accounts for 31.1 percent of scientists, forages 30.2 percent, and beef cattle 20.8 percent The percentage distribution appears consistent with production possibilities. The number of scientists in dairy and beef production may not be sufficient, it is less likely that the job can be done with personnel spread out over many states and several research fields within the states.

6.250 Research themes in the CENIDs. The disciplinary centers study microbial and parasitic diseases. CENID-Parasitology concentrates on two groups--Hemoprotozoans and gastrointestinal and lung parasites--particularly severe in the tropics. CENID-Microbiology is working on bacterial and viral diseases of potential impact. A 1980 study of livestock diseases and pests (Anonymous 1981) estimated Mexico's loss at nearly US$2 billion dollars per year, taking into account mortality and morbidity (low production) and indirect losses (the cost of treatment and of official animal disease-control campaigns). Of the total loss, 78 percent was due to parasites, 12 percent to bacterial disease, and 10 percent to viral diseases.

6.251 CENID-Microbiology has 20.3 percent of the total scientists and 70.1 percent of CENID staff. This unbalanced distribution came about because INIP was initially run from Palo Alto at what is now the CENID-Microbiology site, and achievements in veterinary medicine enabled this group to remain well-staffed and better-equipped.

6.252 Physical facilities. Table 6.14 presents a partial inventory of land and animals at the main stations of the southern region of INIFAP (several stations are absent for lack of information). The physical facilities there handicap research quality. No station has enough animals for genetic improvement work. Herd sizes, particularly dairy, are too small for meaningful comparisons among non genetic treatments on milk production. This is not a problem that can be solved by transferring selection or breeding to private farms, because they have too few stock.

Table 6.14. Tropical Livestock Experiment Stations of INIFAP, Southern Zone, 1989

CIFAP Station	Area Dry	(Ha) Irrig.	Beef	Dairy	Goats	Sheep
Campeche						
China	290		120	20		
Chiapas						
Jerico	23		38	21		
Pichucalco	400		120	19		
Guerrero						
Iguala		56				
Altamirano		20				
C. De Piedra	151	50		127	127	95
Morelos						
Zacatepec		14				
Oaxaca						
M. Romero	265		200	70		
Juchitan		90				
R. Grande	82					
Mixteca		8				
Quintana Roo						
Chetumal	127	12	80	90		180
Panuco						
Aldama	240		20	130		
Ebano		100				
Huchihuayan	150					
Tabasco						
Balancan	170		200	50		
Huimanguillo						
Veracruz						
Isla	105		104	92		
P. Vicente	130					
P. Toro	82	52	52	148		
Yucatan						
Mococha	14	10				1600
Mococha Zh	10	10				
Tizimin	409	16		250		
Uxmal	16	35				
Total	2664	473	934	1017	127	1875

Source: INIFAP.

6.253 Laboratory facilities of the southern region of INIFAP appear in Table 6.15. There are five feed analysis laboratories in the tropics, none fully operative. Equipment there is outdated and old, and cannot last for as many years as in temperate climates. If all the equipment were brought under one roof, it is doubtful that there would be a complete laboratory. Huimanguillo's well-built laboratory facilities have never even equipped.

Table 6.15. Laboratory Facilities in the Southern Zone of INIFAP

Laboratories	Status
Ciudad de Piedra, Guerrero:	
Food Analysis Laboratory:	Incomplete, Non Operative
Mateos Romero, Oaxaca:	
Food Analysis Laboratory:	Incomplete
Aldama, Panuco:	
Animal Health Laboratory:	Incomplete
Chetumal, Quintana Roo:	
Food Analysis Laboratory	Operative
Nitrogen Fixation Laboratory	Operative
Seed Conservation Cool Room	Operative
Glassware And Reagents	Needed
Huimanguillo, Tabasco:	
Large Laboratory Buildings	No Equipment
Paso del Toro, Veracruz:	
Food Analysis Laboratory	Operative with restrictions
Soil Analysis Laboratory	Operative with restrictions
Traimin, Yucatan:	
Food Analysis Laboratory	Operative With Restrictions
Mococha, Yucatan:	
Food Analysis Laboratory	Operative With Restrictions

Source: Mission interviews.

6.254 Current research program. Table 6.16 summarizes proposed experiments in 1989 for the southern region. Though incomplete, the list provided by INIFAP gives an idea of the direction of research. The number of experiments for dairy production and forages reflects well the priority the these two areas receive in almost all stations. Beef production follows in importance (dairy refers to a dual-purpose production, and in that sense overlaps with beef). Many epidemiology projects are related to the monitoring of the station herds and are not independent research endeavors.

6.255 Thematically research distribution is rational (Table 6.16), with appropriate allocations to management, nutrition, reproduction, and breeding. Management includes production modules, both test modules on station and validation modules in farmers' fields. These are not truly experiments, but are a fundamental part of technology development. Breeding projects are few, occupy much of the animal facilities at any station, and take 15-20 years to complete. Breeding work involves too few animals at every site.

Table 6.16. Summary of Animal Production Experiments in INIFAP's Southern Zone, by State and Network, 1989

	Beef	Dairy	Sheep	Swine	Epidemiology	Forages	Nutrition	Reproduction	Animal Breeding	Management
Campeche	4	3	2	0	0	0	1	4	2	2
Chiapas	4	5	0	0	4	14	2	3	2	2
Oaxaca	4	1	2	0	2	0	0	2	3	2
Quintana Roo	0	4	6	0	3	10	2	4	1	2
Panuco	10	3	0	0	9	11	4	5	3	1
Tabasco	15	22	10	0	0	25	15	3	4	25
Tamaulipas	0	0	0	0	0	17	0	0	0	0
Veracruz	32	73	6	11	51	43	31	13	18	60
Yucatan	8	3	17	3	5	22	12	6	6	7
Total	77	114	43	14	74	142	67	40	39	101

Source: Programa De Investigacion 1989, INIFAP

6.256 In primary feeding research, most stations are addressing the problem of lack of feed during the dry season through use of crop residues and industry by-products (including poultry manure). While this work is needed, the stations are doing very similar work. It would be more effective to concentrate work in one or two sites, moving products when needed.

6.257 Use of alkalies and other chemicals is being tried with good results. Sodium hydroxide has become too expensive for use. Where liquid ammonia is available, it is employed successfully if not extensively; there is no work on this at present in the tropics. Technology is well-developed; limitations for its use are price and the attitude of farmers.

6.258 Technology transfer. The principal means of technology transfer is by validation modules with farmers, organized by experiment stations of INIFAP and by the National Autonomous University of Mexico (UNAM). La Posta, Veracruz, is the INIFAP station with the most validation activity. It has four station modules and 15 with small farms. Experience in setting up production models with farms, particularly small ones that have shown important increases in milk and meat production, indicates that returns to investment there can surpass those normally attained in commercial ventures.

3. Other Public Research

6.259 Academic research. Important research is taking place at CPCh and UNAM. CPCh has two centers, one in Tabasco and one in Veracruz, both with strong animal production programs. UNAM has a center in Martinez de la Torre, Veracruz. The Center for Teaching and Research in Agricultural Sciences and Rural Development (CEICADES) in Tabasco is the main center for tropical animal research by CPCh; it works on forages, beef production, dual-purpose cattle, animal breeding, by-products and crop residues as animal feeds, sheep production, and apiculture. The center also has extension activities with farmers training courses, publications, and provision of crossbred bulls to small farmers.

6.260 CIEEGT-UNAM was established in 1978 to conduct beef and milk research; it also works with sheep, swine, poultry, and fresh water fish. Technical and financial assistance from the United Nations Development Program (UNDP) helped fund a project in 1978-87 and one in 1987-90. This center has functional training for medium-level technical people and farmers and has established production modules with five producers. In less than a year of operation, these modules are showing an increase in milk yields and decreases in disease. The center is in close contact with the districts of SARH, but not with INIFAP

6.261 Other research. The PRODERITH program of IMTA has also played an important role in animal production research in the tropics. Diagnoses of production problems of six areas have lead to suggested alternatives ("Diagnostico de la ganaderia bovina" y "Alternativas para el desarrollo ganadera," Serie Divulgacion 21 y 22 del IMTA, 1988 and 1989). PRODERITH has collaborative projects with INIFAP as well.

6.262 An isolated case of private research and extension at the field level is the Tropical Agriculture and Forestry Training Center (CETROCAF), financed by a nonprofit organization. Most of activities are related to extension, but in animal production the center is also testing on cross breeding of cattle and on hair sheep. A milk production module helps train farmers.

Private Research and Technology Transfer

6.263 Private research is rare and usually related to the sale of veterinary and nutrition inputs.

6.264 Veterinary research. Mexico's animal drug industry introduces, processes, and adapts imported patented drugs but does little research. Some technology adaptation adjusts specific drugs to local requirements. Registration of an imported pharmaceutical product is rather simple and requires field testing only for biologicals. Field testing is not considered research and can be done directly with farmers or through an institution such as INIFAP. The National Chamber of the Pharmaceutical Industry (CANIFARMA) coordinates the work of the veterinary drug sector.

6.265 More research is done with animal nutrition products (minerals, energy or protein supplements, and growth stimulants). The strategy of one U.S. firm, Pittman Moore, has been to explore market needs and to review local knowledge; it then prepares appropriate products or does verification research with INIFAP and/or a university. One result is the energy-protein-mineral supplements for cattle sold in Mexico by Pittman Moore. Four fifths of the needed knowledge available from INIFAP; the remaining one fifth came through small contracts with INIFAP and local universities.

6.266 Some technology transfer takes place through marketing activities. One example is the slaughterhouse of the Cattlemen's Association of Tabasco, which has established a milk collection, industrialization, and distribution system. Nestle has a similar collection system and distributes advice, feed, and drugs to milk producers.

Research Achievements

6.267 Animal production research has been less successful than crop research for two reasons. First, it has lacked a dominant objective: research institutions have worked on animal health, breeding, pastures, and forages. Second, livestock production environments are more diverse than those of crops. Mexico's animal production environments vary from the dry areas of extensive cow-calf operations, through intensive milk production in the irrigated highlands, to dual-purpose and semi-intensive cow-calf systems in the tropics. The most successful crops research has been in irrigated areas where it is possible to control the major environmental factor--water. Tropical livestock research cannot do the same.

6.268 Livestock improvement. AI has been successful. The first AI efforts date back to 1936, and by the 1950s a series of AI stations were operating around the country. In the 1960s frozen semen was introduced. Today about 1.6 million doses of bull frozen semen are sold annually, of which 870,000 are imported and the rest are produced by AI stations.

6.269 In the genetic improvement of animals, the Holstein Friesian Breeders Association has run an official milk production control program for about 40 years. The first list of tested bulls was published 16 years ago. In 1988, 55,000 cows were under official control. Approximately 20 young bulls go into progeny testing every year. There are more than 40, mostly private, groups doing embryo transfer on a commercial basis.

6.270 Health. In conjunction with the animal health department of SARH, a country-wide network of 108 laboratories has operated since the 1970s; They have diagnostic capacities for all major diseases and pests. INIFAP's scientists have been involved in the development of vaccines. Appropriate treatments are also available for internal parasites in most regions of Mexico.

6.271 Feed. Much work has gone into the evaluation of feedstuffs in the laboratory and in animal performance. There has been work on crop residues and by-products for animal feeding; mineral deficiencies and mineral mixtures; grasses and legumes irrigated lands and for intensive milk production; fertilization; and weed, disease, and pest control.

6.272 The introduction of new species of grasses and legumes is recent. Andropogon (A. gayanus), Chontalpa (Bracharia descumbens), Insurgente (B. brizantha), Clitoria (C. ternatea) are all available, and 5,000 ha have been planted with these new species in the tropics.

6.273 Management. Over the last 20 years, management packages have been developed for the following production systems:

a. Intensive milk on irrigated lands of the high valleys--this has been economically and technically successful.

b. Intensive milk production on irrigated lands of the subtropics--this has shown technical promise but, its economics are less favorable than in temperate areas.

c. Milk production with dairy breeds in the tropics.

d. Dual purpose production of milk and meat for small producers.

e. Tropical beef production.

D. Other Crops

Introduction

6.274 Mexico's highly diverse agroclimate allows production of many high-value crops--vegetables, tropical fruits, coffee, cotton, sugar cane--that can benefit from scientific investigation. They provide important shares of agricultural exports and of producers' incomes, with potential for future growth.

6.275 Such crops have had mixed responses to private investment in research, extension, and marketing. Some, notably coffee and cocoa, have been subject to incentive failures for private research investment--severe risks from pests and diseases in the tropics, site-specific production systems, many small isolated producers of some crops. Where there is a lack of private national or international research on these crops, expanded public research programs might well step in. In other crops, notably vegetables and fruits, private investment has been highly successful in promoting growth of output, employment, and exports. Hence, priority setting for the public system must consider the different characteristics of crops as they affect incentives for private research and extension.

1. Vegetables

6.276 Vegetable crops are the outstanding example of the impact of private research and extension. From 1960, when they were a small percentage of the value of national crop output, vegetables have grown to 16.6 percent. Exports of them have grown at an annual rate of 5.5 percent in quantity, and now provide roughly 40.0 percent of the value of agricultural exports.

6.277 The principal vegetables are tomatoes, cucumbers, melons, onions, and chilies. Those crops, grown with irrigation, constitute 75 percent of output and 41 percent of the volume of exports. Production is concentrated in the states of Sinaloa (triple the production of the next largest state), Baja California, Sonora, Michoacan, and Tamaulipas. These five states have 83 percent of output.

6.278 The INIFAP program in vegetable crops is weak. The horticulture network has 41 staff, of whom 14 are in the north, 11 in the center, and 16 in the south, while 22 have MSc degrees, only 5 have PhDs. Table 6.17 shows research priorities for the principal crops of the network. Review of planned experiments by network (Table 6.18) shows that only 3.8 percent of the experiments for 1990-94 are planned for vegetable production. This is low in comparison with the area, value, or export shares of these crops. While the contributions of imported and private research are high in these crops, it is clear that the public national program cannot provide leadership in the field.

Table 6.17. Horticultural Research Programs in INIFAP

Crop	Problems	Strategy	States
CHILE SERRANO	Virus,	IM, Breeding	Tamaulipas, Nayarit, Sinaloa, Sonora, Hidalgo, etc.
	High Temperatures	Breeding	Tamaulipas and Veracruz
	Leaf Miners	IM	Tamaulipas, Veracruz and Nayarit
	Pod Borer	Chemicals	Tamaulipas, Veracruz, Nayarit and Sonora
	Pod Wilt	Breeding	San Luis Potosi, Coahuila, Nuevo Leon, Nayarit and Hidalgo
CHILE JALAPEÑO	Virus	IM	Veracruz, Nayarit, Sinaloa, Chihuahua, Campeche, Quintana Roo, Tabasco, Michoacan and Bajio
	Lack of Varieties	Breeding	Veracruz, Nayarit, Sonora, Sinaloa, Chihuahua, Campeche, Quintana Roo, Tabasco and Michoacan
	Pod Wilt	Breeding	Veracruz, Sonora, Sinaloa and Chihuahua
	Leaf Miners	Chemicals	Veracruz, Sonora, Chihuahua, Quintana Roo, Tabasco and Michoacan
	Pod Borer	Chemicals	Veracruz, Sonora, Chihuahua, Quintana Roo, Tabasco and Michoacan
CANTALOUPE	Virus	IM	Michoacan, Jalisco, Nayarit, Tamaulipas, Veracruz, Colima, Sinaloa, Sonora, Laguna, Chiapas, Campeche, Yucatan and Baja California Norte
	Wilt	IM	Michoacan, Jalisco, Nayarit and Colima
	Mildew	Chemicals	Michoacan, Jalisco, Nayarit, Colima, Tampico and Veracruz
	Moth	Chemicals Breeding	La Laguna, Baja California Norte and Sonora
	White Fly	Chemicals	Michoacan, Nayarit, Colima, Jalisco, Tampico, Veracruz, Sonora and Sinaloa
SQUASH	Virus	IM	Sinaloa, Sonora, Tamaulipas, Bajio, Nayarit, Michoacan, Baja California Norte, Puebla, Morelia and Veracruz
	Low Temperatures	Microtunnels	Sinaloa, Sonora and Baja California Norte
	Lack of National Hybrids	Breeding	Sinaloa, Sonora and Baja California Norte
GREEN TOMATO	Lack of Varieties	Breeding	Morelos, Puebla and Guanajuato
	Moth	Chemicals	Morelos, Puebla and Guanajuato

Source: INIFAP.

Table 6.18. Planned INIFAP Experiments by Network

	Experiments 1990-94	
	Numbers	Shares
Maize & maize associations	6,435	10.2%
Grain Legumes	5,144	8.2%
Small Grains	3,664	5.8%
Forages	3,545	5.6%
Agricultural Systems	3,225	5.1%
Entomology	3,112	4.9%
Temperate Fruits	2,932	4.7%
Oilseeds	2,726	4.3%
Water/soil/plant relations	2,619	4.2%
Vegetables	2,373	3.8%
Plant Pathology	2,351	3.7%
Forestry Improvement	2,029	3.2%
Tropical Fruits	1,904	3.0%
Socioeconomics	1,746	2.8%
Soil & Water Conservation	1,551	2.5%
Sorghum & Millet	1,478	2.3%
Forestry Management	1,429	2.3%
Weeds	1,381	2.2%
Milk	1,251	2.0%
Land Use	1,219	1.9%
Seed Technology	1,114	1.8%
Information	995	1.6%
Beef	968	1.5%
Roots & Tubers	886	1.4%
Tropical Industrials	834	1.3%
Non-Wood Species	753	1.2%
Goats	597	0.9%
Epidemiology	492	0.8%
Sheep	487	0.8%
Technical Innovation	484	0.8%
Post-Harvest	465	0.7%
Fires	331	0.5%
Pigs	315	0.5%
Urban Wood	291	0.5%
Fibers	283	0.4%
Forest Products Storage	279	0.4%
Firewood	256	0.4%
Ornamentals	255	0.4%
Poultry & Minor Species	253	0.4%
Domestication	204	0.3%
Mechanization	182	0.3%
Halophytes	103	0.2%
Animal Product Technology	46	0.1%
Bees	39	0.1%
Aquaculture	20	0.0%
Work Animals	5	0.0%

Source: INIFAP.

6.279 Private research and extension are important in horticulturals. The National Organization of Vegetable Producers (CNPH) has more than 22,000 individual grower-members, organized in 245 local associations in 27 regional associations. Typical of a regional branch is the Confederation of Agriculture Associations of Sinaloa (CAADES), which has a research, extension, and lobbying unit funding with $800,000 from an export levy. It has private members only and does not accept ejidatarios, though other regional associations of CNPH do. In Sinaloa, typical producers' associations provide services to members, including input sale, fuel deliveries, extension advice, soils analysis, seed storage, and marketing advice. They support INIFAP research via a fee paid on the fertilizer price to the Permanent Commission for Agricultural Research in Sinaloa (CPIAES).

6.280 CNPH's research activities include testing commercial hybrids and developing its own lines. It can use imported materials for local adaptive testing in collaboration with foreign companies and, sometimes, with foreign universities. CNPH does not have a germplasm collection and INIFAP has a very limited one. Other lines of research include integrated pest control on watermelon and irrigation water management (mainly timing). There is little or no research on mechanization or post-harvest technology.

6.281 CNPH has research agreements with INIFAP (diseases of cucumbers, melon, squash, and chile), the University of Antonio Narro (biological control of watermelon fungus), and the Center for Research and Advanced Studies (CINVESTAV--tomatoes). CNPH is also considering the creation of an autonomous research center.

2. Coffee

6.282 Production. Coffee production is concentrated in Chiapas, Veracruz, Oaxaca, and Puebla. Production in 1989 was about 750,000 mt on 740,000 ha. There has been a long-term increase in production, largely from growth of area; yields have risen only at 1.1 percent annually since 1950. About 55 percent of national production is now exported, though the share was higher in 1950-65.

6.283 Research by INMECAFE. INMECAFE does coffee marketing, research, and extension (but marketing will be dropped within three years). It conducts research in five areas of Veracruz, Chiapas, and Puebla, with its main station at Xalapa, Veracruz. INMECAFE research involves 20 scientists, 30 technical staff, and an annual research budget of MEX$3 billion. While INMECAFE can organize convenios with producers' groups (there are 14 in coffee), it has not done so. There are apparently no producer contributions to coffee research of INMECAFE or of INIFAP, and revenue from the export levy on coffee does not explicitly fund research.

6.284 The principal subject for INMECAFE research is plant breeding for coffee improvement. Until 1958 Mexico used Cuban and Guatemalan coffee varieties, and Brazilian varieties entered in the late 1950s. Use of these historical materials led in 1978 to the development of the Guernica variety, now the dominant one. With respect to genetic resources, INMECAFE maintains about 1,000 materials at six different sites and faces no special restrictions in importing materials except the usual quarantine measures.

6.285 INMECAFE research also includes agronomy, plant pathology and entomology, processing, and machinery development; it has completed a national coffee census (1982) and a coffee atlas and does special studies on areas for seedling nurseries. The institute does technology transfer through 74 support centers established in 1987. It has made recommendations in the areas of land preparation, varieties, planting date, pruning, weed control, and harvest.

6.286 Research by INIFAP. INIFAP's main coffee research is at Xalapa. The program, begun in 1981 in response to the introduction of coffee rust into Mexico, is much smaller than INMECAFE's, with only seven scientists. Research is similar to that of INMECAFE, the main difference being that the latter uses tissue culture methods, for which INIFAP lacks facilities.

6.287 INIFAP has identified the principal problems of coffee production as old, low-bearing, trees, lack of improved varieties, and weeds (rust is unimportant, except in lower altitudes). It does technology transfer with the same producers groups as INMECAFE. It has not written convenios to finance research but has them for technology transfer. There apparently was a short-lived coffee patronato in Puebla state, but it is not clear that it did anything.

6.288 Because of the overlap between the coffee research programs of INMECAFE and INIFAP, there was an explicit division of labor in 1985. The program (Programa Nacional Conjunto de Investigacion en Cafe, INIA-INMECAFE) proposed 145 experiments with durations from 3 to more than 20 years, and assigned work on given themes and areas to each institute. A Comite Interinstituto (3 members from INMECAFE and 3 from INIFAP) was established to coordinate work but does not appear to function.

3. Tropical Fruits

6.289 Production. Mexico's diverse agroecology permits production of a wide variety of deciduous and tropical fruits. Beginning from a small area after World War II, overall fruit production has grown at 3.1 percent annually and exports at 4.4 percent. The share of exports remained between 6.8 and 9.2 percent from 1950 to 1985. Tropical production is concentrated in Michoacan (avocado), Veracruz (citrus), Veracruz and Oaxaca (mango), Nayarit, Chiapas, and Veracruz (plantain), and Chiapas (papaya). The share of all fruits in the real value of output has grown from 8 percent in 1950 to 14 percent in 1985.

6.290 Research by INIFAP. Research priorities are shown in Table 6.19. Priorities were based on a 1977 plan to establish principal sites for each crop: Chiapas for plantains, Nuevo Leon and Veracruz for citrus, Aguascalientes for guava, and Michoacan for avocado.

Table 6.19. Tropical Fruit Research Programs in INIFAP

Crop	Project
Citrus	Harvest Date Fruit Quality Disease Resistance Tree size
Avocado	Mineral Nutrition Germplasm Collection
Mango	Tree Size Disease Resistance
Plantains	Crop Improvement Disease Resistance
Papaya	Breeding Resistance to Ring Spot Virus
Pineapple	Breeding Resistance to Wilt, Root Fungi, and Nematodes

Source: Mission Interviews

6.291 Network staff in tropical fruits are few, and only three have PhDs. The congruence of staff allocation with the value of output of crops is: avocado, 0.57; orange, 0.57; mango, 0.88; plantain, 0.91; and papaya, 0.73. These values are lower than for other crops, indicating that limited resources are too widely dispersed.

6.292 INIFAP's capacity is weak in genetic resources for tropical fruits (Table 6.20). In some of the main species, the collections are quite old. Exchanges of germplasm with international sources appear to be good, but there is little capacity to catalog or distribute them.

Table 6.20. Sources of Tropical Fruit Germplasm

	Papaya	Mango	Citrus	Avocado
Principal source of germplasm	Tropical America	Florida; India	SE Asia, Florida, California	Mexico
Collections	1965 in Veracruz	1970 in Culiacan, Veracruz, Chiapas	1962 in Nuevo Leon Culiacan	1971 in el Bajio
Sources of new material	Nicaragua, Colombia, Cuba, Hawaii, Florida, Venezuela	Thailand, Philippines, Hawaii, Puerto Rico, Florida	California	None
Other crop improvement work outside	None	None	CONAFRUT	CICTAM in Mexico

Source: Mission Interviews

6.293 Other research and extension. The recently dissolved parastatal CONAFRUT provided research and extension that included selling breeding stock to producers. Some private and government orchards outside CONAFRUT have also sold breeding stock. There is little foreign investment in Mexican tropical fruits. CNPH has recently begun to work on mango and citrus, though its contributions are minor.

4. Cotton

6.294 Production. Historically cotton has been one of the two major agricultural exports of Mexico, the other being coffee. Cotton production has collapsed in the last 15 years. Mean area of 855,000 ha from (1950-65) has fallen to 411,000 ha (1966-85), although yields actually rose. The value of output fell from an average of annual Mex $229 billion in 1950-65 to an average annual Mex$143 in 1966-85. INIFAP staff argue that the reasons for the collapse of cotton are to be found in low domestic price, pests and diseases, and high production costs caused by competition from other crops.

6.295 Research. Cotton research began in the late 1950s in Chihuahua, Chiapas, and Baja California Norte, with other sites being added in the 1960s and 1970s. As most of the varieties in use were from North America, early research concentrated on cropping practices and irrigation management. Recommendations were made on planting dates and densities, numbers and dates of irrigations, and pest control. Mexican varieties began to be released in 1973, and eight have been released to date.

6.296 INIFAP ranks the cotton research problems as water scarcity, soil salinity, low temperatures, high temperatures, pests, diseases, weeds. The 1990-94 INIFAP research plan has proposed few experiments in the fibers (cotton and henequen) network (Table 6.18); only 0.4 percent of planned experiments are to be done there. This is extraordinarily low, given that cotton still occupies a major share cropped area, is still a major export, and lacks private research. The puzzling aspect of the cotton program is that so little is done about the drop in area. Strong emphasis is put on yields and this has paid off; yields have nearly doubled.

5. Sugar Cane

6.297 The parastatal National Sugar Company (AZUCAR) has responsibility for sugar production, research, and extension. One of AZUCAR's predecessors (UNPA) was private from 1949-69, having been formed by mill owners. The National Sugar Industry Commission (CNIA), formed in 1970, became AZUCAR in 1983. Within AZUCAR research and extension is IMPA.

6.298 Research by IMPA. At IMPA, research is done by one of four subdirectorates. Until 1989, there were 300 scientists; this number is being reduced to 180, of whom 120 are technical staff. With a research budget of roughly Mex$10 billion, IMPA has 10 experimental sites, the largest at Veracruz.

6.299 IMPA's research is one-half in crop improvement, plant pathology, and agronomy, with the rest in technical assistance and extension. Plant breeding is necessarily a long-term effort with slow changes in the composition of varieties used by farmers. Of the materials now in use, about 60 percent are Mexican and 40 percent are foreign.

6.300 Access to foreign germplasm is adequate. Sources include Hawaii, India, Taiwan, Australia, Brazil, Argentina, Colombia, Jamaica, and the United States. The only restrictions on imported germplasm are quarantine, as two diseases (rust and smut) have been introduced from the outside. All imported material enters at Chetumal, Quintana Roo, and it undergoes one year of quarantine and one of multiplication; hybridization then takes place in Chiapas. A Mexican collection consists of about 1,778 entries at Tapachula, Chiapas, begun in 1943 with a gift of 102 lines to one of the mills.

6.301 The intent of sugar policy is to privatize all mills and to fund research from mill operations (essentially the system until 1970). There is already some private sugar research, in that larger mills hire private consultants and a few Mexican firms offer management assistance.

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