Guatemala's seed industry has been built upon a partnership of public sector agricultural researchers who are charged with the development of improved varieties and on the efforts of private seed growers, such as this farmer, who produce the commercial seed of the new high-yielding maize varieties.

maize research and production in guatemala

The maize research and production program of Guatemala has made important contributions to Guatemalan farmers, to CIMMYT's own maize research program, and to the national research efforts of other countries.

After less than a decade of existence, the Institute for Agricultural Sciences and Technology (ICTA) has built the basis for a much brighter future for Guatemalan maize production. ICTA hybrids and varieties, and recommended production practices—now used on half the lowland area—are giving average yields 1.3 t/ha (30 percent) higher than those obtained with the varieties and agronomic practices previously used. In the highlands, where the production constraints are more complex

and difficult to overcome, farmer trials show promise that ICTA varieties and technology can achieve 4.3 t/ha, 70 percent above the yields obtainable with traditional varieties and practices.

On the average, each Guatemalan consumes 350 g per day of maize, the dominant food staple of that Central American country. Virtually every Guatemalan farmer is a maize grower—at least to satisfy his own family's need for this vital cereal grain. Roughly 45 percent of the country's arable land is planted to maize (see box: A Profile of Guatemala).

Despite the significance of maize in the Guatemalan diet and the large amount of human effort devoted to maize production, Guatemalan planners and agriculturists by the late 1960s saw serious productivity problems associated with the crop. Yields were low and maize imports, fueled by a rapidly growing population, were on the rise. Indeed total basic food production in the country was not keeping pace with domestic demand and the country's subsistence farming sector was becoming larger in absolute numbers.

Faced with this situation, Guatemala embarked on a major new rural development plan in which a central goal was the transformation of the basic food production capacity of the country. In 1970, the Guatemalan Congress passed significant legislation aimed at reorganizing the public agricultural sector. The key characteristic of this reorganization was a decentralization and regionalization of public sector activities in agricultural research, extension, credit, and market development (see box: Guatemala's Public Agricultural Sector). Another policy shift was the designation of basic food producers, and in particular, small and intermediate size producers, as the primary clientele of public sector agricultural institutions.

From the beginning, the Guatemalan government targeted most of its national research efforts on maize and other basic food crops. Agricultural leaders knew that yields could be substantially increased, but that a new and different type of research orientation would be needed to transform basic food production in Guatemala.

ICTA, a key element in the government's agricultural development plan, was established in 1973 as a decentralized agricultural research institute within the public sector. As part of ICTA's early institutional development strategy, the government of Guatemala entered into an agreement with the United States Agency for International Development (USAID) and CIMMYT to assist in developing ICTA's maize improvement and production research program. CIMMYT assigned two maize scientists to work within the national maize research program between 1976 and 1980.

A PROFILE OF GUATEMALA

Population: 7 million (1981)
Land Area: 108,889 sq. km.
Gross National Product: $6.93 billion (1979)
Per capita GNP: $1,020 (1979)
Labor Force: 57 percent in agriculture (1980)
Arable Land: 1.4 million ha (1980)
Cereal Crops: 900,000 ha
Maize Area: 600,000 ha

ICTA'S MAIZE PROGRAM

ICTA's maize research and production program has two key features: (1) an integration of disciplines at the research level; and (2) a strong commitment to on-farm research as the most effective way to develop and verify improved technology.

Some research activities—those centered primarily on experiment stations—are carried out by researchers assigned to the national maize program. These researchers, in turn, work in close cooperation with regional production research teams charged with planning and conducting on-farm research activities. Close coordination also exists between national maize researchers and the technicians of ICTA's Seed Production Unit who are responsible for getting improved varieties into commercial seed production.

Guatemala is situated in the tropics. The altitude varies from sea level to about 4,000 meters in the volcanic highland axis running west to east throughout the country. The climate ranges from tropical in the lowlands to subtropical to temperate in the highlands. Rainfall ranges from 2,000 mm per year in certain lowland areas to less than 500 mm per year in some semi-arid valleys. Distinct wet and dry seasons exist in major crop production areas.

Roughly 57 percent of Guatemala's labor force is engaged in agriculture. Ethnically, 44 percent are considered Indian, 52 percent *Ladino*[1/], and 4 percent European.

The social structure and ethnic make-up of Guatemala have distinct regional characteristics. The population has been concentrated in the highlands, where a number of distinct Indian (Mayan) languages and dialects are spoken. In the western and central portions of the highlands, the population is predominantly Indian. In the eastern highlands, the population is *ladino*. Along the Pacific south coast, the population is also primarily *ladino*.

Guatemala has a dualistic agricultural sector. It has a dynamic export-oriented sector which accounts for considerable foreign exchange earnings (coffee, sugar, cotton). The major commercial production area is found along the Pacific coastal plain. This strip, which ranges in width from 35 to 60 km, is the center for cattle, cotton, and sugarcane production, as well as for other basic food crops. Most farms are intermediate in size. In the piedmont areas, considerable coffee is produced in addition to basic food supplies.

In much of the higher central and western highlands, food production is of a subsistence nature. Farms are usually small and land holdings are often fragmented. Commercial food production is mainly centered on wheat, with good yields obtained in some areas. In the lower altitude eastern highland areas, agriculture is more commercially oriented. Most farmers are small landholders engaged in basic food production.

New colonization projects are opening up in piedmont and lowland areas in the northern part of the country. Considerable potential exists for expanded commercial food production in these areas during the 1980s.

1/ The term ladino is a cultural definition referring to those indigenous people who follow 'western' cultural practices and speak Spanish as their first language.

GUATEMALA'S PUBLIC AGRICULTURAL SECTOR

Following the 1970 reorganization of the public agricultural sector, several centralized and decentralized institutions were created, all under the overall responsibility of the Minister of Agriculture. New institutions included ICTA, responsible for agricultural research on basic food crops; BANDESA, an agricultural development bank which extends credit to small and intermediate size farmers; INDECA, an agricultural commercialization institute; and INAFOR, a natural resource and forestry conservation institute. Remaining Ministry of Agriculture activities were consolidated under DIGESA, the General Directorate of Agricultural Services, primarily responsible for agricultural extension, the promotion of basic food production, irrigation development, and seed certification, and DIGESEPE, which provides technical assistance and extension services to livestock producers.

ICTA, DIGESA and BANDESA all have regional programs. Area directors for all three organizations are members of a coordinating committee chaired by the DIGESA regional director. Through this organizational structure, more decision-making has been decentralized to the local level.

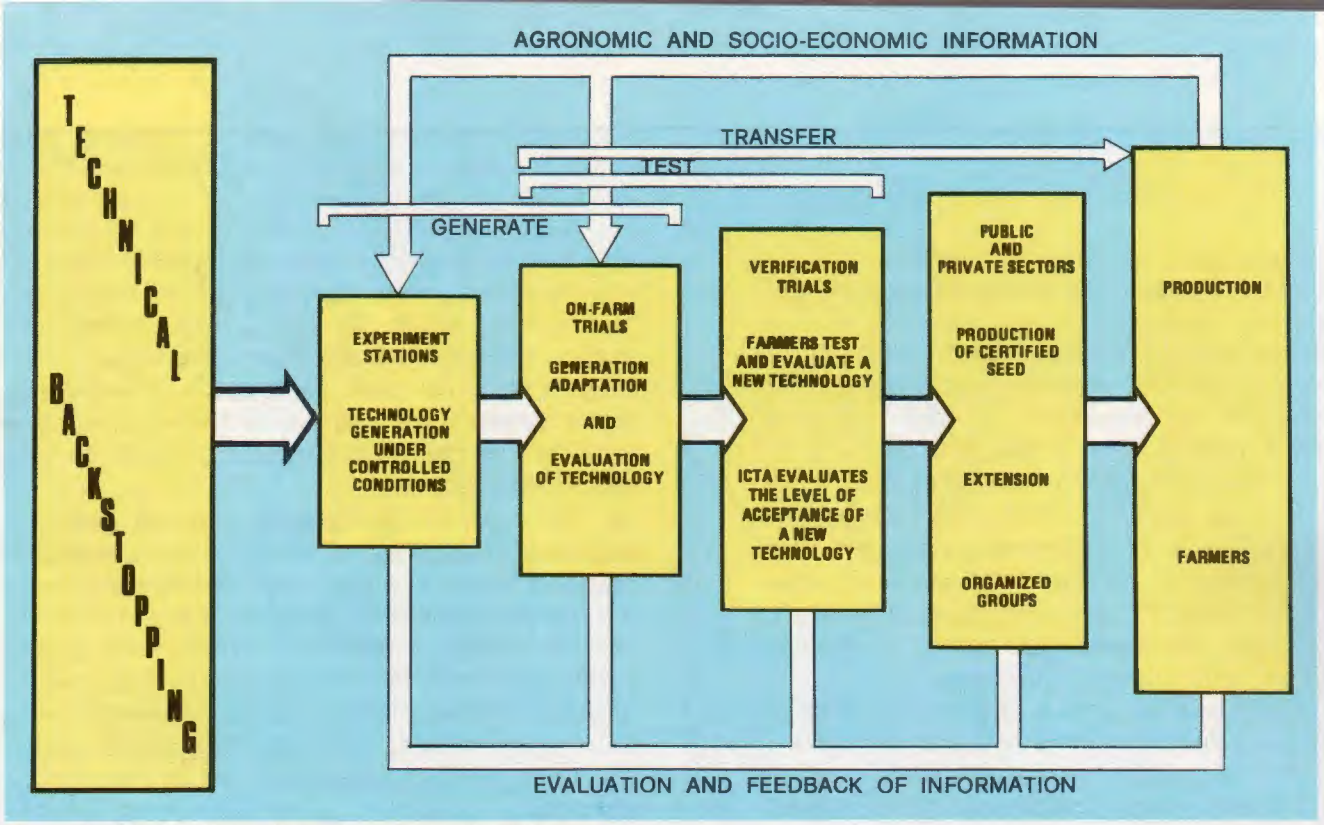


Figure 1. ICTA's Research System—Operational Sequence

ICTA scientists have concentrated their efforts on two major agroclimatic zones. The first is a tropical lowland zone covering production areas between sea level and 1,000 m altitude. This zone accounts for over half of Guatemala's maize-growing area (about 360,000 ha) and approximately two-thirds of national production. The second zone covers the highland areas above 1,000 m (about 240,000 ha) and includes most of Guatemala's subsistence farming sector where many of the country's four million rural inhabitants live.

The ICTA Research System

In the ICTA system, researchers begin their investigations in each maize-growing area with a series of agronomic and socio-economic surveys (Fig. 1). Conducted by regional production research team members and ICTA social scientists, the surveys are exploratory in nature and are directed at identifying and ascertaining the circumstances and practices of farmers in the target area.1/

Results of the survey allow researchers to identify groups of farmers for whom a given technology—variety and practices—should produce roughly similar results. The profiles of these farmer groups are then used to establish priorities for research.

Technology Generation

In most cases, ICTA begins experimentation under controlled conditions, usually on experiment stations (see box: Station-Based Research). These research activities center mainly on the development of improved varieties with superior agronomic performance, and tolerance to stress situations including resistance to prevalent diseases and insects. Superior germplasm supplied through CIMMYT's International Testing Program (described later) serves as a useful element in ICTA's maize improvement strategy. Within this strategy, research is focused on the two major agroclimatic zones .

Lowland Zone—In most of the lowland agroclimatic zone, agriculture has a commercial orientation. Farmers are more accustomed to buying agricultural inputs as well as to marketing their crop commercially. Many area farmers began in the 1970s to buy hybrid maize seed.

To serve farmers in this zone, ICTA developed two closely related breeding programs. One strategy was to develop high-yielding varieties that were competitive in yield with hybrids, and that had superior agronomic characteristics for Guatemalan production conditions. Using an improvement strategy built around a recurrent selection scheme

1/ *Farmers' circumstances here refer to all those factors which affect a farmer's decisions about a crop technology—his natural environment (e.g., soil type, rainfall) economic environment (e.g., product markets, land tenure), his goals (e.g., increased income, food preferences, risk avoidance) and his resources (e.g., seasonal cash and labor availability).*

ICTA hybrids and varieties are extremely popular among maize farmers in the lowland zone. This farmer has used ICTA seed for two years. The 5 t/ha yield he is now obtaining is almost 70 percent higher to what he harvested before.

to accumulate superior genes in desired maize types, ICTA scientists were able to develop high-yielding open-pollinated varieties. These improved varieties are now in farmers' fields and have the added advantage that their seed can be saved from season-to-season with little loss in yield potential—an option not available to the farmer using hybrid seed.

Since many lowland farmers were already accustomed to buying hybrids, ICTA scientists also set out to develop Guatemalan hybrids to capture the growing national market for hybrid maize seed. Here they opted to develop non-conventional hybrids called "intervarietal" and "family" hybrids, which could reach commercial release faster than would be possible with conventional hybrids. Both research strategies have proved to be successful (see box: ICTA's Certified Varieties and Hybrids for Lowland Areas). A range of ICTA varieties and hybrids have been developed and favorably received by Guatemalan farmers.

Highland Zone—For the highland zone, ICTA concentrated its efforts on the development of varieties whose seed could be saved by farmers from year-to-year without loss in yield potential. Such varieties, reasoned ICTA's maize scientists, would be more appropriate to the highland areas where most of Guatemala's subsistence farmers reside and where farmers are less accustomed to purchasing seed.

ICTA'S CERTIFIED LOWLAND VARIETIES AND HYBRIDS

Most of the improved high-yielding varieties and hybrids released by ICTA through 1980 have been for lowland production areas. These include five hybrids and two open-pollinated varieties. In 1981, the following quantities of each lowland tropical variety were available for spring planting. Virtually all of this certified seed was purchased by agribusiness stores or by individual commercial maize growers. Additional cropland areas were also planted to ICTA varieties using seed saved from previous harvests.

Name	Grain Color	1981 Seed Availability (tons)	1981 Production Coverage (ha)
La Maquina***	White	462	31,000
ICTA-B1***	White	462	31,000
T-101**	White	462	31,000
HA-44*	Yellow	200	13,500
HB-33*	White	150	10,000
HB-11*	White	130	8,700
HA-28*	Yellow	80	6,000
Total		1,946	131,200

* Family hybrid—Refers to a hybrid made from crossing two selected families from different populations
** Inter-varietal hybrid—Refers to a hybrid made from crossing two open-pollinated varieties
*** Open-pollinated variety

ICTA scientists have developed promising new varieties for the major highland zones. These varieties have high-yield potential, earlier maturity, and shorter plant height compared to traditional materials. Pictured here is CIMMYT scientist Ing. Hugo Cordova, who worked directly within the ICTA maize program for four years before assuming regional CIMMYT responsibilities in Central America and the Caribbean.

Within the highland zone, ICTA scientists focused their efforts in two subregions: the western highlands, where most cropland is above 2,000 m altitude, and the central highlands, where most of the farmland lies between 1,500 and 2,000 m altitude. Because of the substantial agroclimatic variation within each subregion, ICTA scientists moved preliminary germplasm development activities off experiment stations and onto farmers' fields. Researchers began their improvement activities by collecting germplasm from farmers' fields and from ICTA and CIMMYT germplasm collections. These materials were then compared in special yield trials at a range of highland locations. Some materials—'traditional' and 'improved'— showed superior yielding ability across many of the test locations. ICTA researchers took the most promising germplasm back to their research stations for further improvement for a range of plant characters. This approach has resulted in a number of broadly adapted varieties which have shown considerable promise in on-farm trials and verification plots.

By 1980, four yellow grain high-yielding varieties for highland areas had been certified for commercial sale. Two are full-season varieties well adapted to the high valleys of the western highlands. Both varieties are less than 2.25 m in height and are considerably less susceptible to lodging than traditional varieties (3 to 4 m in height). Two other varieties recently released are for slightly lower areas in the central highlands. These varieties are considerably shorter than traditional varieties; one is also considerably earlier to maturity. Several more varieties are expected to be released by 1982, including some particularly early-maturing types (see box: ICTA's Certified Varieties for Highland Areas).

All of these open-pollinated varieties have plant types that are less than 3 meters in height. Chanin and Don Marshall are slightly less than 2 meters in height. The others are in the 2 to 3 meter range. Chanin, which is particularly 'early', is well-suited to highland farmers who wish to intensify their production by adding a second season crop.

On-Farm Research

ICTA has decentralized a large portion of its maize research activities to regional programs. Within the ICTA research system, interdisciplinary production research teams conduct farmer surveys, on-farm experiments, technology verification, and some training-related activities associated with

ICTA's efforts to strengthen the capacities of its staff have been an integral part of its institutional development strategy. The ICTA scientist, on the left recently completed his M.S. degree in Mexico and the other attended in-service training at an international agricultural research center.

transferring recommended technologies. Administratively, production research team members report to regional directors, although their maize-related research activities are planned and executed in close collaboration with the national maize program staff.

ICTA'S CERTIFIED VARIETIES FOR HIGHLAND AREAS

The following varieties either have been, or are expected to be, released by ICTA before 1982 for highland areas.

Name	Grain Color	Area of Adaptation (altitude)
ICTA 606 (Toto-Amarillo)	Yellow	2,300–2,700
San Marceño	Yellow	2,000–2,500
ICTA V-302	Yellow	1,500–1,700
ICTA V-304	Yellow	1,500–2,000
Don Marshall*	Yellow	1,500–2,000
Chanin*	Yellow	1,200–1,500

* 30 to 60 days earlier to maturity than full-season varieties.

Socio-Economic Studies

Scientists in the headquarters-based socio-economic section, in conjunction with the regional on-farm production teams, conduct initial production surveys in areas targeted for research attention. These informal surveys provide needed information on farmer circumstances and production practices and help to identify collaborating farmers for subsequent on-farm experimentation.

On-Farm Experimentation

On-farm experiments are planned using data gathered from farm-level surveys and from experiment station trials. These activities are carried out by interdisciplinary regional production teams. Of the 1,174 total research trials conducted in 1980 by ICTA scientists, 1,006 were on farmers' fields, an indication of the importance ICTA places on adaptive research.

The first year of on-farm experimentation in a particular target area is designed mainly to increase the understanding by production team researchers of the circumstances of area farmers and the reasons behind the production practices

they pursue. Researchers work closely with participating farmers, who share some of the management responsibilities associated with the trial. In the second year, fewer technological alternatives (best bets) are included in on-farm trials. By this stage, researchers have a much better idea of what is needed in the area and know whether ICTA has a viable technology to offer. Those varieties and agronomic practices which show significant economic promise in these trials are next recommended for inclusion in larger plot verification trials.

Technology Verification

ICTA scientists provide the principal planning and evaluation of experimental technologies under study in the on-farm trials. However, at the verification phase, participating farmers are asked to manage the treatments included in the verification plot on their land. These plots are of sufficient area (usually 1/2 ha in size) to conduct production-scale evaluations. They usually include only one or two alternative technologies alongside the farmer's traditional variety and practices. ICTA scientists do provide some technical assistance and record complete production cost information. However, the primary responsibility for each of the verification plots rests with the cooperating farmer.

The following season ICTA scientists evaluate farmer acceptance of the alternative technologies previously included in verification plots. If a significant number of the farmers who grew the verification trials have adopted one of the recommended varieties and production alternatives, then ICTA formally recommends the technology to the Extension Service of DIGESA for wider promotion among Guatemalan farmers.

Even after production recommendations have been formulated, ICTA's regional production teams continue to monitor farmer practices and to maintain production cost data associated with the use of ICTA-recommended maize production technology.

Technology Transfer Training Activities

Regional production research team members, along with the national maize program staff, are also increasingly involved with the DIGESA staff in field days which serve as a mechanism for

STATION-BASED MAIZE RESEARCH

ICTA has 10 experiment stations (production centers) located across the seven regions in which maize improvement and agronomic research are carried out. Each region has its own set of research priorities based on the agroclimatic and farmer circumstances which characterize the major maize-growing areas.

In the breeding work, a population improvement system is used. Multiple selection criteria are formulated according to the problems which exist in each area where a population is meant to serve. A number of maize populations have been developed to serve the major grain preferences and agroclimatic requirements of the country. These populations are in a continuous process of improvement.

ICTA scientists have used their improved maize populations in several ways. They have pulled the best families out of a particular population and made them into an open-pollinated variety. They have taken selected experimental varieties from different populations and used them as parents to develop "intervarietal hybrids." They have used individual families from different populations as parents to develop "family hybrids."

Each year, this dynamic improvement process continues to spin off new experimental varieties and hybrids derived from a constantly improving base of different maize populations. In recent years, ICTA scientists have given emphasis to increasing the disease resistance and adaptation to limited moisture in their materials. This research is carried out in collaboration with the national maize research programs of El Salvador and Honduras. Quality protein maize (QPM) materials have also been tested for several years with promising results. Yields of over 8 t/ha have been obtained in research station trials. The best QPM entries in on-farm rainfed trials carried out in one region in 1980 had an average yield of 4.4 t/ha across all locations.

On-farm researchers play a key role in ICTA's maize improvement and production research system. Through a continuing dialog with representative farmers, ICTA scientists are better able to keep their research focused on the critical production problems facing Guatemalan maize farmers.

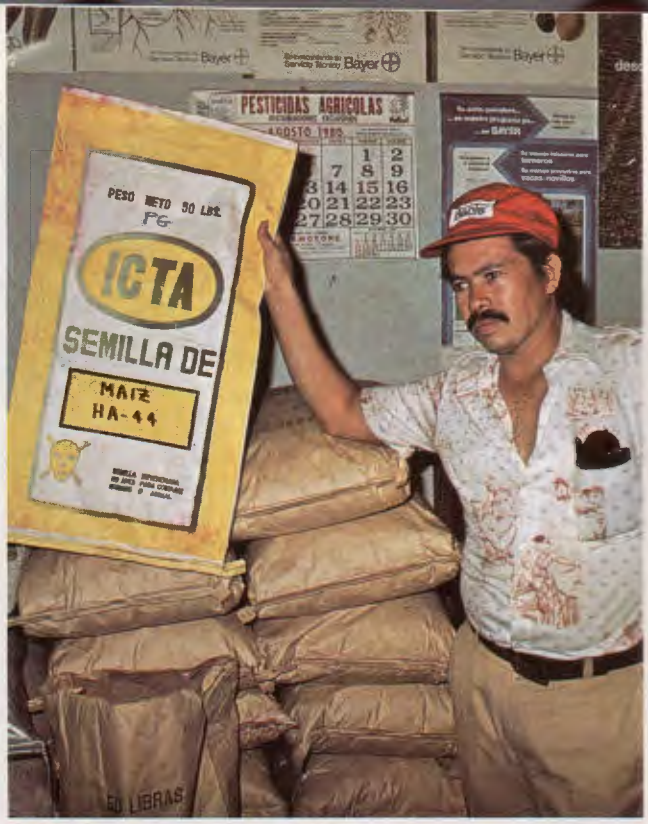
As part of the national maize improvement program, ICTA participates in the CIMMYT international maize testing program as well as in the Central American (PCCMCA) regional maize yield trials. These international trials serve as a source of introduction of new germplasm into ICTA's breeding efforts.

Early in the life of the national maize program, CIMMYT's experimental variety trials allowed ICTA scientists to select some relatively 'finished' varieties for almost immediate release to Guatemalan farmers in certain areas.

Even as the stock of improved germplasm has increased in Guatemala, considerable use continues to be made of international nurseries. The nurseries are a source of new germplasm to maintain breadth in the genetic base of materials undergoing improvement at ICTA. Guatemala also benefits from the regional testing network of PCCMCA in the sense that some of the best national materials become entries in trials tested at stations in other countries of the region. Widespread testing of these entries provides Guatemalan scientists with information on the performance of their best materials at dozens of test sites.

The other major type of research conducted at experiment stations is focused on problems related to agronomy. In particular, trials to evaluate alternative chemical control methods of insects and diseases are conducted on experiment stations first, to guard against unknown side effects associated with different treatments. Some time-of-planting, density, and tillage studies are also conducted on stations (as well as on farmers' fields).

Stations also serve as logistical and training centers for the on-farm research programs conducted within each of ICTA's administrative regions.



With assistance from the Inter-American Development Bank, ICTA has helped to establish an effective national seed industry capable of the timely delivery of seeds of high-yielding varieties. Dr. Federico Poey, formerly assigned by CIMMYT to the Guatemalan maize program (left photo, center), played an important role in this national seed industry strategy.

extending agricultural information to farmers. Such gatherings, sponsored by ICTA and DIGESA, are also an effective method of obtaining feedback regarding ICTA-recommended technology and for improving communication between ICTA researchers, other public sector agricultural workers, and farmers.

In addition, regionally assigned ICTA staff offer special workshops for DIGESA staff members and other technicians assigned to public sector organizations. At these workshops, ICTA staff members present recent research results which have possible application for area farmers. In-service training short courses in agricultural sciences are also offered in each region to extension workers and to new ICTA staff members as part of an on-going program of professional improvement for agricultural technicians.

Seed Production of ICTA Varieties and Hybrids

Perhaps one of the most important links in the Guatemalan strategy to raise maize yields has been the efforts to develop a national seed industry. Guatemala's national seed industry plan is built around a close public-private sector partnership. In this partnership, ICTA names and releases new varieties and individual farmers produce this seed under the supervision of ICTA and DIGESA technicians (see box: ICTA's Seed Unit).

ICTA'S SEED UNIT

ICTA's Seed Unit staff members carry out a wide range of responsibilities in support of Guatemala's national seed industry strategy.

Foundation Seed

The Unit has responsibility for producing sufficient quantities of foundation seed to serve private sector cooperating growers as well as the seed requirements for research from within the institute. The multiplication of foundation seed is carried out on regional ICTA experiment stations (production centers) located strategically throughout the country. Maize accounts for 85 percent of ICTA's seed activity, although the multiplication of foundation seed of certified varieties of beans, rice, sorghum, sesame, and wheat is also a responsibility of the Unit.

Certified Seed Production and Supervision

Ninety per cent of the certified maize seed produced in Guatemala is grown by private producers who have registered with ICTA and DIGESA's Department of Seed Certification. The remaining 10 per cent of Guatemalan certified seed is produced by ICTA on government experiment stations.

Quality control is an important element in successful seed production. Pictured here are Ing. Marco Tulio Aragon (right), head of DIGESA's seed certification department, and Ing. Julio Gonzalez del Valle (left), coordinator of ICTA's seed unit, inspecting the fields of one of Guatemala's private seed growers.

Frequent visits to the fields of private growers are made by ICTA seed technicians. These visits serve several purposes: they allow the seed unit staff to extend technical assistance, they permit the monitoring of the fields of seed growers, and they help keep scientists abreast of the performance of the materials released by ICTA which are in production. These supervisory activities are extremely important to the maintenance of quality standards within the national seed industry.

Processing and Marketing Services

The Seed Unit also offers processing and short-term storage services to the private growers. For a reasonable fee, any grower can send his seed to ICTA facilities near Guatemala City for processing and bagging in ICTA certified seed sacks. All seed sold in ICTA bags has the location and responsible grower listed on attached labels.

ICTA production centers sell seed to growers living in the vicinity as well as to private agroservice stores located in many farming communities. Advice is also provided to individual growers on how to market their seed directly to distributors and local agroservice stores.

ICTA's Seed Commission, made up of five senior staff members, sets general price guidelines on the wholesale and retail price of its certified varieties, hybrids, and experimental lines. The Commission, in particular, attempts to ensure that sufficient profit exists for seed growers and retailers to maintain product quality and effective distribution.

Close and continuing contact between ICTA scientists and Guatemalan farmers is a major characteristic of the institute's strategy to generate improved technology. Here, Ing. Alejandro Fuentes (left), coordinator of the national maize program, interviews a Pacific south coast farmer who estimates that he will harvest 4.5 t/ha with his new ICTA variety.

Both ICTA and the Ministry of Agriculture's Department of Seed Certification maintain quality control over ICTA varieties for commercial sale. Without this certification, no private grower can use ICTA varietal names on his commercial seed. ICTA also provides wholesale and retail price guidelines for its hybrids and varieties.

Despite the preference assigned to the private sector in commercial seed production and processing, ICTA is also directly involved in the production of some seed of its varieties and hybrids to maintain quality control and price stability in the market. ICTA also offers seed processing services and short-term storage facilities to independent private growers at a reasonable cost. These services are particularly useful to the small growers who may find it difficult to get small quantities of seed processed at the private plants operating within the country.

The response has been strong for private growers to become involved in seed production of ICTA varieties and hybrids. A national association of seed growers was formed in 1979 and annual meetings are now held. Since 1976 the growth in seed sales of ICTA maize varieties has risen steadily. In 1976, 318 tons of maize seed were produced and only 136 tons sold. In 1980, 1,200 tons of seed were produced and all were sold. In 1981, 2,000 tons of maize seed—a seven fold increase over 1976—will be on the market. ICTA estimates that over 175,000 ha will be planted with high-yielding ICTA hybrids and varieties in 1981. Projections for 1982 call for the production of 3,200 tons of seed of ICTA hybrids and varieties, sufficient to plant 225,000 ha primarily below 1,000 meters in altitude. (In addition, many farmers growing improved open-pollinated ICTA varieties will use seed saved from previous harvests.) The total area, therefore, planted to ICTA varieties and hybrids, should surpass 70 percent of the total maize area under 1,000 m in altitude and 40 percent of Guatemala's total land area devoted to maize production—a remarkable change in only six years.

Research Impact on Production

The yield impact of ICTA varieties and recommended technologies on maize croplands below 1,000 m in altitude has been impressive. Nearly 50 percent of the farmers in lowland

Regionalization of research priorities is central to the ICTA program organization. Here, Ing. Bladimiro Villeda (left), ICTA's general manager, Ing. Alejandro Fuentes, and Ing. Ricardo del Valle (right), director for ICTA's Region V in the highlands, inspect a new early-maturity highland variety.

This farmer obtained a yield of 6.5 t/ha in 1980 from his one 'manzana' (about 0.7 ha) of land using the open-pollinated variety ICTA B-1.

Well-targeted crop improvement research is needed for the take-off of any successful seed industry.

areas are now planting ICTA varieties and hybrids. The average yield (4.8 t/ha) from many on-farm trials using these improved varieties and ICTA production recommendations is 1.3 t/ha higher than the best potential yields obtained using traditional varieties and practices. Published Bank of Guatemala agricultural statistics (1980) show that national maize production increased from 555,200 tons in 1976 to 845,000 tons in 1979, with about 34 percent of this increase due to yield improvements. In large part, this progress can be attributed to the government's research and production efforts in lowland areas. The availability of high-yielding ICTA hybrids and varieties has also eliminated most of the demand for imported maize hybrids (1,300 tons of hybrid seed were imported in 1978). Thus, ICTA's efforts to develop a national seed industry have also resulted in considerable foreign-exchange savings for the country.

To date, ICTA's maize research efforts in the highlands have not achieved the same production impact as evidenced in the lower elevations. The problems limiting yields in this zone are more complex and more difficult to overcome, yet the prospects from recent research activities conducted by ICTA scientists in this higher altitude zone offer high hopes for the 1980s. In farmer-conducted verification trials in 1979 of ICTA's highland zone varieties and recommended technologies show that the producer can obtain 4.3 t/ha using ICTA seed and technology, compared to an average yield of 2.5 t/ha for the trials using traditional varieties and technology. A recent survey, carried out by ICTA scientists in the important western and central highland areas, revealed that nearly half of the farmers contacted were using, at least on some of their land, part or all of ICTA's recommended varieties and production practices.

Particularly valuable are a number of short-season and short-statured (less than 2.50 m) high-yielding varieties. These materials mature 60 days earlier than traditional varieties, allowing farmers many new production options. With such varieties, the highland maize producer will be able to get in a second crop each year (perhaps wheat or potatoes), with sufficient residual moisture to obtain good yields. Traditional long-season maize varieties are too late maturing to offer this intensification option. ICTA scientists are hopeful that these early varieties will achieve good acceptance during the 1980s. If this scenario takes place, it will result in the first major impact on raising yields in the highland maize zone since the introduction of fertilizer .

ICTA and the International Maize Testing Program

In the development of improved high-yielding maize varieties, ICTA scientists have made effective use of the broad range of germplasm available from CIMMYT each year as part of the international maize testing program. On a request basis, many improved maize populations have been sent to ICTA. Some of the best performing materials in these trials have been selected and improved further, according to national breeding objectives. For example, ICTA B-1 is a version of CIMMYT's Tuxpeño-1 population. Before releasing this material, ICTA scientists improved the husk cover to decrease field losses of grain.

Superior selections made from the international trials grown in Guatemala have also gone beyond national boundaries. For example, ICTA scientists selected a variety in 1974 at La Maquina, Guatemala, from an international progeny testing trial (IPTT 22). This selection then became a variety at the experimental level (called La Maquina 7422) and was tested by many national programs. It was later released as a commercial variety in Guatemala, called La Maquina, and released in

Honduras, Costa Rica, Nicaragua, and the Ivory Coast under various names.

Sustaining Success

ICTA began life as an institution with high expectations and a highly motivated staff. It developed a dynamic research orientation in which the farmer was clearly the primary research client. As part of its institutional development strategy, ICTA leaders mapped out a sound program of staff development. A national program of in-service training was designed to develop new staff. In addition, international advisors, such as the maize scientists deputed from CIMMYT and from other international organizations, were invited to participate in the ICTA program, generally on a fixed-term basis, while bright and promising ICTA technicians were sent out for advanced training, most enrolling in graduate programs in Mexico, Brazil, and the United States.

Within the maize program, 50 percent of the professional staff now has advanced-degree training. By 1980, the need to retain full-time international advisors was no longer necessary. A solid human and scientific base has been laid to sustain the research momentum built up over the preceding five years. Equally important, ICTA has a viable research strategy that can continue to generate, validate, and recommend improved technology to Guatemalan farmers.

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