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The United Nations Development Programme is the world's largest source of multilateral pre-investment and technical assistance. Established in 1965, through the merger of the UN Special Fund and the Expanded Programme of Technical Assistance, UNDP support the efforts of low-income countries to develop their natural resources and human capabilities, and to attract the capital needed for financing both economic and social progress.

As of mid-1973, the Programme was supporting more than 6,000 projects in 135 developing countries and territories. These projects, valued at $3.7 billion, provide international experts, equipment and fellowship opportunities to help meet such basic development needs as:

- -Surveying and evaluating natural resources and other economic assets for use in agriculture, industry, power production, transport, trade and other key sectors;
- -Training teachers, vocational instructors, managers, engineers, technicians, skilled craftsmen and other essential personnel;
- -Strengthening public administration and development planning capabilities;
- -Combatting disease and developing permanent public health services;
- -Adapting and applying modern productive technologies;
- -Stimulating the flow of investment capital;
- -Encouraging economic co-operation among neighbouring countries,

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A UNITED NATIONS
DEVELOPMENT
PROGRAMME
GLOBAL
PROJECT

# RESEARCH AND TRAINING IN THE DEVELOPMENT OF HIGH LYSINE MAIZE

UNDP

CIMMYT

## PREFACE

The United Nations Development Programme is the world's largest source of multilateral pre-investment and technical assistance. Established in 1965, through the merger of the UN Special Fund and the Expanded Programme of Technical Assistance, UNDP supports the efforts of low-income countries to develop their natural resources and human capabilities, and to attract the capital needed for financing both economic and social progress.

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* Strengthening public administration and development planning capabilities,

* Combatting disease and developing permanent public health services;

* Adapting and applying modern productive technologies;

* Stimulating the flow of investment capital,

* Encouraging economic co-operation among neighbouring countries.

UNDP-supported projects are designed to form part of co-ordinated country or regional programmes covering periods of from three to five years. These integrated programmes are drawn up by the governments of the low-income nations themselves in the context of their basic needs and priorities and are approved by UNDP's 48-member Governing Council.

A network of almost 100 Field Offices located throughout Asia, Africa and Latin America assists in formulating and implementing these country programmes. Virtually all projects are carried out in the field by one or more of the 17 international agencies of the United Nations system. The field work of these agencies is co-ordinated by the UNDP Resident Representatives, who also act to coordinate bilateral and private development assistance with that of the United Nations system in the countries where they serve.

The Programme's Administrator, who has over-all responsibility for UNDP operations, maintains close contact with the field through four Regional Bureaux - covering Africa; Asia and the Far East; the Americas; and Europe, the Mediterranean and the Middle East. The Administrator is responsible to the 48-nation Governing Council which reports through the Economic and Social Council to the UN General Assembly.

UNDP operations are financed through the voluntary contributions of countries all around the world, rich and poor alike. Nations receiving the UNDP's help pay more than half of project costs themselves and also provide the majority of the personnel for project staffing. One indication of the Programme's universality is that more than 60 different nationalities are represented on its headquarters staff in New York alone.

Since 1959, more than $9 billion in follow-up capital investments have flowed, directly or indirectly, from UNDP-supported surveys and feasibility studies. During the same period, over one million citizens of low-income countries have received specialised training under UNDP auspices.

## INTRODUCTION

On 11 March 1973, the initial phase of the first global project to be approved by the Governing Council of the United Nations Development Programme (UNDP) was concluded. This project, which was carried out over a three-year period under a direct contract with UNDP by the International Maize and Wheat Improvement Centre (CIMMYT) at El Batan in Mexico, had as its objective the establishment of a programme of research and training directed towards the development of high lysine maize and of superior maize lines.

CIMMYT was an outgrowth of over twenty years co-operative effort between the Government of Mexico and the Rockefeller Foundation to improve the basic food crops of Mexico. The Centre was set up in 1963 when the Government and the Rockefeller Foundation decided to disseminate to the rest of the world some of the greatly improved varieties of maize and wheat and improved production technology which had been developed. Soon, however, it was found that the demand was greater than the two original parties could satisfy and in 1966 the Centre was reorganized with the additional participation of the Ford Foundation. In that year, CIMMYT was established in accordance with Mexican law as an autonomous international research and training institute under the direction of a board of trustees of international repute and eminence. This structure provided CIMMYT with the needed freedom of operation for its world-wide programmes and enabled it to seek financial support from all those interested in advancing its goals.

In May 1970, a Consultative Group on International Agricultural Research (CGIAR) - sponsored jointly by the World Bank, the Food and Agriculture Organization of the United Nations (FAO), and the UNDP - was established. The following Governments and agencies are participating: Belgium, Canada, Denmark, the Federal Republic of Germany, France, Japan, the Netherlands, Norway, Sweden, Switzerland, United Kingdom, United States of America, Ford Foundation, Rockefeller Foundation, Kellogg Foundation, Canadian International Development Research Centre, Inter-American Development Bank, Asian Development Bank and the African Development Bank. Other Governments and organizations have since joined the CGIAR which also counts amongst its participants two developing countries from each of the five major regions of the world. The latter participants serve as members or alternates at their discretion.

The CGIAR is unique in that it brings together not only Governments and international institutions but also the Ford, Rockefeller and Kellogg Foundations, which have played pioneering roles in the whole area of international agricultural research, and the Canadian International Development Research Center. The purpose of CGIAR is to encourage a greater research effort aimed at assisting developing nations to increase

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and improve the quality of their agricultural output. It reviews existing research activities and explores major new areas of possible investigation, taking into account not only the technical but also ecological, economic and social factors. The CGIAR's objectives include helping to synchronize national and international agricultural research efforts and encouraging full exchange of information among national, regional and international research centres; discussing the financial requirements for high-priority international and regional research activities, keeping in view the need for continuity of research over a long period; undertaking a continuing review of research priorities in the light of needs of the developing countries; and suggesting feasibility studies on proposals to meet these needs.

A small Technical Advisory Committee composed of distinguished international experts from developed and developing countries was established by the CGIAR. This Committee is responsible for advising the CGIAR on the principal gaps in agricultural research and on the international and regional programmes which deserve priority in filling those gaps.

In addition to CIMMYT several other International Research Centres have been established, and are financed by the CGIAR and/or by its members. These are the International Rice Research Institute (IRRI), Philippines; the International Tropical Agriculture Centre (CIAT), Colombia; the International Institute of Tropical Agriculture (IITA), Nigeria; and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India. UNDP has provided financial support for the establishment of ICRISAT.

These Centres have demonstrated a high level of professional and administrative competence and have a substantial potential as a vehicle for the deployment of international assistance to agricultural research. This competence has been amply demonstrated by CIMMYT in executing the High Lysine Maize project. UNDP has accordingly allocated a substantial sum for global projects under direct UNDP execution through contracts with the International Agricultural Research Centres.

The results on the development and initial introduction of high lysine maize documented in the following pages indicate substantial promise of not only considerably enhanced food production in maize consuming areas, but also the potential for a variety of far reaching benefits through substantially improved nutrition of both the human and livestock populations in many areas of the less developed world.

Much has been said and written about the critical protein deficiencies currently of widespread importance in many parts of the world, including predictions of even more serious protein deficiencies in the future.

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Filling the protein needs of vast numbers of people with low incomes, through added amounts of meat, milk or synthetic protein supplements appears to be very difficult. Human infant and child nutrition studies conducted under this maize project have demonstrated that the new high lysine maize can substitute satisfactorily for milk as the only protein source even for infants and is quite adequate for older children and adults.

Because maize is the basic food for the lower income families in many areas of the world, this offers a promising means of correcting past protein deficiencies without any diet change or other requisite other than shifting varieties of maize.

One of the basic research problems has been to develop maize varieties with the high lysine characteristic that are of the traditional type and quality preferred in the various regions utilizing maize. The original maize discovered with high lysine has characteristics unacceptable to people in most maize eating areas.

Under this project rapid progress has been made in developing maize of the various types utilized which include the high lysine factor. Initial material is being widely evaluated and its supply increased in various parts of the world. Other efforts have included solving the problems of lower yield and greater susceptibility to damage from disease and insects originally associated with the high lysine type. Rapid progress has been made in solving these problems and experimental lines are now available equal to the best maize varieties in these characteristics.

Introduction of the new high lysine maize if properly carried out - a function performed by farmers as well as Governments - offers the opportunity for simultaneous introduction of improved production techniques which will vastly increase maize yields. The new high lysine varieties being introduced have much superior yielding ability compared with the native varieties. The same improved protein quality characteristics greatly enhance the value of this maize as a feed for livestock, particularly swine and poultry. This provides the potential for lower feed costs and greater production efficiency to produce meat and eggs in the future.

UNDP assistance has also helped to increase the capacity of CIMMYT to assist national Governments to conduct adaptive research, extension programmes, field demonstrations and farmer training in improved technology of cereal production, with particular attention to the high lysine and high-yielding varieties of maize, in several countries. The project initially supported work in Colombia, Ecuador, Honduras, Mexico and Peru, and this work is now being expanded in other countries both in Latin America and in other regions of the world.

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In presenting this CIMMYT report, it must be understood that the development of this new technology will not by itself solve the problem of production and nutrition. It is the responsibility of governments to adapt the new technology to the people's needs. In this effort, which is the real "pay-off", UNDP is prepared to consider providing the additional assistance required.

CONTENTS


| | |
|---|---|
| ORIGINS | 6 |
| A scientific breakthrough | 6 |
| The concept of international research and application | 7 |
| United Nations involvement | 8 |
| THE PROPOSAL | 9 |
| Research problems | 9 |
| Work plan | 10 |
| PROGRESS | 11 |
| Genetic Research and Breeding | 11 |
| Chemical and Nutritional Research and Analytical Service | 18 |
| Latin American Developments | 21 |
| THE FUTURE OUTLOOK | 29 |
| CIMMYT's role 1973-1976 | 29 |
| Services offered to developing nations | 30 |

## ORIGINS

Civilization of man evolved around cereal foods and their domestication. Up to, and including the present time, cereals have provided mankind's principal source of carbohydrates and energy. Often overlooked is the fact that cereals, even today, provide the largest single source of protein in the diet of most of the earth's people.

Per Cent of Total Protein Supplied by Cereals in the Current Food Supplies of World Regions (Compiled from FAO food balance sheets).

| Region | Per cent of total protein from cereals. |
|---|---|
| Europe | 37 |
| North America | 20 |
| Latin America | 40 |
| Far East | 58 |
| Africa and Near East | 60 |
| Oceania | 25 |

In general, however, cereals are not a well balanced food. They often lack sufficient quantity of proteins. And in terms of quality, these proteins have an inherently unsatisfactory nutritional balance of amino acids such as lysine and tryptophan, which are essential for the proper growth and health of man. Unfortunately, a large proportion of the people living in tropical and subtropical countries in Central and South America, Africa and Asia exist on diets consisting largely of cereals and consequently suffer varying degrees of protein deficiency.

Although many suggestions, and some actual attempts, had been made to alleviate this protein deficiency by the use of animal protein, legume protein, leaf protein, fish meal, and even supplementation with synthetic amino acids, the impact on the problem of feeding protein deficient people has been insignificant. Among all of the basic cereals, maize is one of the most widely consumed, and, traditionally, it has been one of those with the lowest protein quality.

### A scientific breakthrough

In 1963, Dr. E.T. Mertz and his co-workers at Purdue University discovered that the mutant gene "opaque-2" of maize produced a modified amino acid balance of the grain endosperm protein. This resulted in increased quantities of lysine and tryptophan, opening up exciting new vistas for plant scientists, breeders and human and animal nutritionists.

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Feeding trials with opaque-2 maize confirmed that animals, particularly the young, could gain weight up to three and a half times faster than if fed normal maize. The growth rates and standards of health were roughly equivalent to growth patterns resulting from artificially balanced diets. Children suffering from severe protein deficiency in Colombia have been brought back to normal health in two to three months on a diet of opaque-2 maize.

The implications of this breakthrough were immediately obvious to many scientists. Biochemical, physiological and genetic mechanisms of the amino acid mutant came under detailed study. Searches were initiated in other cereal crops such as wheat, barley, sorghum, etc., for similar amino acid mutants, and breeding and feeding programmes were also started.

By the beginning of 1970, a great deal of valuable information had resulted from this work, but there had been virtually no impact of this research on the real problem - the nutritional welfare of the maize-eating populations of the less developed areas of the world. It was doubtful whether localized research was likely to have a widespread impact. However, a new concept of international research and application had been evolving that could possibly provide the competence, structure and know-how necessary to co-ordinate, supplement and, more importantly, put into practice a quality protein maize programme which might eventually influence the lives of a large number of protein deficient people in the developing world.

## The concept of international research and application

Unless knowledge developed from scientific agricultural research is applied to areas of human welfare where it is needed, it becomes merely sterile science. This viewpoint underscored the first Rockefeller Foundation agricultural assistance programme, initiated at the invitation of, and with the collaboration of, the Mexican Government nearly 30 years ago.

Agricultural technology was recognized as an essential, but not sole element in increasing food production. The process requires a complex, broad-scale effort that includes such components as incentives for farmers, availability of seed, fertilizers, pesticides, agricultural credit - and a whole series of government policies that are not limited to agriculture. Also important is the training of research and production people to expand and supply the new materials, technology and philosophy, and adapt them to the needs of their own countries. This holistic approach was developed along with the creation of new high yielding, widely adapted, fertilizer responsive populations and varieties of cereals. So successful was the concept in Mexico, that it led to the evolution of international agricultural research centres, such as the International Rice Research Institute (IRRI) in the Philippines, and the International Maize and Wheat Improvement Centre (CIMMYT) in Mexico.

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These developments produced the so-called "Green Revolution", but it was only a beginning. Many countries were requesting assistance to raise the level of productivity of their farm lands, and whole regions remained untouched by this revolution. An equally serious problem was that of protein deficiency, because even in those areas where cereal grains were supplying sufficient carbohydrates, there still existed a deficit of adequate quality protein for good health and growth.

United Nations involvement

In 1968 the United Nations published a report entitled "International action to avert the impending protein crisis" (E/4343/Rev.1). The report had been prepared by an ad hoc Panel of Experts and submitted to the United Nations Advisory Committee on the Application of Science and Technology to Development. The Advisory Committee subsequently proposed fourteen specific measures for attacking the problem. Two of these measures are of particular relevance to this report.

> Specific Proposal 1: Support increased production of conventional animal and plant sources of protein by all feasible means.
>
> Specific Proposal 4 (c): Develop and support projects for the prompt introduction of improved varieties such as corn with higher lysine and tryptophan contents, and glandless cotton seed.

In January 1969, at the invitation of the Rockefeller Foundation, Executive officers of UNDP, FAO, IBRD and private, national, and regional assistance agencies met for the first of several informal meetings at Bellagio, Italy, to discuss ways of utilizing and funding the expertise of existing and projected international agricultural research centres.

Concurrently, the 48-nation Governing Council of the UNDP became increasingly concerned with the application of basic and applied research for social and economic development. This concern culminated in the following decision at the Council's eighth session (16 June-2 July 1969):

> The Governing Council "attached great importance to UNDP activities in the various fields of basic and applied research, on programmes which are related to the solution of regional and interregional development problems involving the implementation of new technology through the support of existing or new research institutions in the developing countries, and authorized the Administrator to waive counterpart contributions from the requesting Government or Governments for this type of project to be submitted under the normal procedure of UNDP".

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This decision enabled the UNDP to initiate action to become officially associated with the ongoing international basic agricultural research, which had already achieved remarkable results with respect to rice and wheat. Now, the UNDP was ready to provide additional financing with a view to intensifying these efforts and to facilitate worldwide dissemination of the results which would hopefully contribute to increased food production.

## THE PROPOSAL

On 4 August 1969, CIMMYT submitted to the UNDP a detailed proposal for research, development and utilization of high lysine maize. At the recommendation of the UNDP Administrator, the Governing Council approved the proposal at its ninth session, and on 12 March 1970, CIMMYT and UNDP agreed on a three-year programme with the following broad objective:

> "The purpose of the project is to assist the peoples of the developing countries in improving the protein content of their diet through:
>
> (a) intensifying research on raising the quantity and quality of protein in maize in combination with high yield;
>
> (b) training agronomists to carry out national programmes of nutritive maize production...".

The funds for the CIMMYT project amounted to $1,653,200, with activities limited to Central and South America. Dr. Ernest W. Sprague, Director of the CIMMYT International Maize Programme, was named team leader with responsibility for carrying out of the project. CIMMYT agreed to convene a Policy Advisory Committee consisting of one representative of each of the Governments involved in project activities; FAO, designated as an advisory agency; and UNDP. A CIMMYT officer was to be Chairman of the Committee, which was required to meet periodically, as determined by CIMMYT, but at least twice a year.

### Research problems

In early 1970, when Global One started, there were several technical problems to be overcome before high quality maize could be produced by the farmers of Latin America. It was not certain at that time whether all the problems could be resolved. The principal problems were:

(a) The original opaque-2 and floury-2 mutants were identified in varieties of maize ecologically adapted to the temperate

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climate of the United States "corn belt". They were not suitable for direct production in the tropical and sub-tropical areas where they could produce the greatest benefits.

(b) The descriptive names "opaque-2" and "floury-2" indicate the dull, lustreless and chalklike physical appearance of the kernels by which these mutants were originally isolated and identified. These characteristics represented an obstacle to acceptance by farmers accustomed to growing flint and dent types of maize with their clean, shiny and lustrous appearance. Apart from the high Andean regions of South America where the floury grain types are traditionally grown, the majority of the maize areas of the world grow flint and dent types for either human or animal feed.

(c) The grain of these mutant maize has a soft and less dense endosperm with a lower weight per unit volume which reduced yield by an average of 10 to 15 per cent.

(d) There were indications that the mutants were more susceptible to insect and disease attack and were therefore more difficult to store.

(e) The only certain method of identifying high quality maize was by chemical analysis of the grain for lysine and tryptophan. This highlighted the need for a simple, accurate and rapid analytical technique for measuring the quantity of these amino acids in very small quantities of grain endosperm.

## Work plan

The project was divided into three distinct but interrelated areas of activity:

I. Genetic research and breeding, necessary to provide a range of maize populations and varieties which are not only high in lysine and nutritive value, but also have improved yield and agronomic characteristics, together with acceptable grain type to meet local requirements in selected Latin American countries.

II. Chemical and nutritional research and analytical service, necessary to provide:

(i) a more efficient analytical technique for identifying single maize grains with high lysine and tryptophan content; and

(ii) an analytical service for the geneticists and breeders to enable them to identify nutritively superior genetic materials.

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III. Training and assistance in the initiation and operation of nutritive maize production programmes (NMPP's) in Latin American countries. Pending the availability of satisfactory quality maize varieties from the genetic research and breeding programme it was decided to initiate the following activities:

(i) survey countries in Central and South America to determine those with large subsistence maize farming areas that were willing to co-operate in the project;

(ii) select agronomists from the country or countries, for training in Mexico;

(iii) assist with the initiation and operation of a Nutritive Maize Production Programme in the country; and

(iv) organize local, regional and international meetings to encourage the interchange of information and experience at all levels, including farmer organizations, Government agencies, Government leaders and scientists.

## PROGRESS

### Genetic Research and Breeding

A small opaque-2 maize breeding programme at CIMMYT was expanded in 1970 to transfer the opaque-2, or $o_2$ gene from its original, unadapted genetic background into a wider range of maize varieties and populations from most of the maize-growing areas of the world. The transfer of the $o_2$ gene into locally adapted maize was also underway at a number of other breeding centres. CIMMYT was able to assemble approximately 75 different $o_2$ maize populations which were at various stages of development. About half of these were from the Mexican programme and the rest have come from programmes in 15 other countries. These materials form the basis of the present quality maize breeding programme. The following pages describe some of the principal breeding objectives:

#### Development of quality protein maize materials

CIMMYT is placing special emphasis on the incorporation of the quality protein characteristic into all the breeding populations within the maize programme. In this way, there is an automatic parallel development of normal and quality protein versions of all superior populations and varieties with various grain types from tropical, temperate and high altitude areas of different countries.

As the process of opaque-2 conversion proceeds, some information about general trends of effects on converted materials is accumulating as follows:

(a) The transfer of the opaque-2 gene into normal flint and dent maize varieties changes the physical appearance of normal grain into opaque, dull, chalky and lustreless grain. This can be overcome through further breeding and selection.

(b) There is considerable fading of colour, especially in yellow grain types. The degree of fading, however, varies considerably with different genetic backgrounds.

(c) There is an increase in the levels of lysine and tryptophan. Increases of the order of 43 to 200 per cent of tryptophan in the protein have been found in different genetic materials.

(d) The percentage of protein in the endosperm in opaque-2 converted materials generally decreases. This decline may range from 3 to 35 per cent. Some materials, however, do not follow this trend. They tend to maintain the protein content at the same level, or register a slight increase.

(e) In general, opaque-2 kernels have lower kernel density than their normal counterparts. In some genetic backgrounds the decrease in test weight has been negligible.

Although several of these trends are generally unfavourable for the breeders, there is sufficient genetic variability to ensure that the combination of quality protein and other desirable plant characteristics are being rapidly assembled through effective selection procedures.

Wide adaptability

Historically, maize has been one of the most location and environment specific crops grown by man. However, if the benefits of quality protein maize are to have widespread value, it must be incorporated into varieties which are capable of producing high yield over a wide range of locations. In a short period of time it is not possible for CIMMYT to produce individual varieties for every environmentally different location in developing countries. Because of lack of manpower and expertise, most of these countries are unable to produce this type of variety for themselves.

By selecting offspring of all breeding materials at six sites in Mexico, which differ in latitude and altitude, plus the assistance of collaborators to select in Colombia, Egypt, Nigeria, Thailand, and the United States, rapid progress is being made towards widening the adaptive range of the CIMMYT breeding populations. Breeders select twice per year at several of the above test sites.

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## Pest and disease resistance

Because of the different pests and disease that occur in these different environments, a strong selection pressure is also applied for a broad type of resistance. Entomologists and pathologists are also creating artificial infestations of insects and disease to speed up this process and make it more reliable.

## Plant type

In the lowland tropics, maize grows far too tall, resulting in loss of yield because the plants fall over, and also because too much of the carbohydrate synthesized during growth is used for tall stalks instead of seed.

CIMMYT breeders are making considerable progress in shortening the tropical maize plant by selecting for short plants, or by crossing specific dwarfing genes into the populations. The resulting varieties and populations can be grown at much higher plant populations, and respond to higher levels of fertilizer without falling over. The yield potential promises to be considerably increased for tropical maize.

This work is being assisted by physiologists and agronomists, who are also assisting to define other desirable characteristics. Populations which have a much shorter maturity period are being produced. These can be fitted into multiple cropping systems and thus increase total production of food per hectare per year.

## Grain type

A breeding objective of prime importance for successful adoption of quality protein maize is the production of a wide array of hard endosperm flint and dent grain types, equivalent to those used in various parts of the world. Considerable emphasis has been placed on this aspect of the programme during the past three years. More than 20 maize populations are being selected for varying fractions of hard, vitreous endosperm while retaining the protein quality.

Genetic studies have shown that the opaque-2 gene for quality protein is a single genetic factor, and therefore easily handled and maintained within a breeding programme. To combine this protein quality with a hard vitreous grain, however, requires the accumulation of many modifier genes, or genes of small individual effect that must be combined in sufficient numbers within a particular family or variety to produce the required grain type.

The rate of progress towards converting various populations and varieties to a hard, vitreous grain type with quality protein varies according to the frequency of modifier genes that occur within them. Much of the early enthusiasm for breeding quality protein maize in the

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United States was lost because the breeders were unable to convert their highly specific maize hybrids into quality types with hard grain. The narrow genetic base of United States hybrids and lack of sufficient modifiers provides the reason for this lack of success.

CIMMYT breeders, using populations based on widely different genetic materials, have been able to make rapid progress towards this goal. However, populations vary considerably in the frequency of useful modifier genes that they contain. This variation will continue to impose limitations on the breeders with regard to the rapidity with which they can convert some of the populations to hard endosperm, quality protein form.

Apart from the need to provide a grain type acceptable to the farmer, there are other reasons for requiring hard endosperm. First, the soft starchy nature of the opaque-2 normal grain results in a lower specific gravity of the grain. This, in turn, results in a yield loss of 10 to 15 per cent on a weight basis. Hard endosperm types have been produced that have grain specific gravity equivalent to normal flint and dent maize.

Another reason is that the soft grain types appear to be more vulnerable to disease and insect attack in the field and in storage. Recent research indicates that this is probably due to the soft endosperm and not the higher nutritive quality of the grain. The genetic sources of quality protein also bring with them greater susceptibility to pests and diseases, thus reducing the inherent resistance often present in local populations. Some of the quality maize families that have been converted to hard endosperm forms show that these problems can be overcome.

In May 1972, CIMMYT breeders harvested the first bulk seed sample - 100 kilogrammes, approximately 4 bushels - of a maize population carrying the opaque-2 gene, hard endosperm grain. The maize was resistant to many common diseases, it had an intermediate maturity (i.e. 110-115 days in the hot season in the tropical lowlands of Mexico), and it displayed a good yield potential under tropical conditions in the best farmer's fields (5-6 tons per hectare in the cool season and 3-4 tons per hectare in the hot season near Poza Rica, Mexico). Most of this 100 kilogramme harvest was immediately shipped by air for multiplication and testing in 15 countries: Colombia, Ecuador, Egypt, El Salvador, Guatemala, Haiti, Honduras, India, Mexico, Nepal, Nigeria, Pakistan, Panama, Philippines, and Thailand.

The resulting seed is being used for field trials on farmers' fields in each of these countries; test feeding of swine and small animals; and test feeding of protein deficient children in a hospital at Cali, Colombia. A preliminary report from Dr. Pradilla, who is conducting the Colombian clinical tests with children, states "The quality of both whole grain and endosperm is very similar to that of casein when B.V. (Biological Value) and N.P.U. (Net Protein Utilization)

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are considered...In summary I would say that the modified endosperm has a very high nutritional value somewhat better than values obtained for the soft endosperm types".

Several more quality maize populations with hard endosperm grain will be available for testing and production within the next year or two.

The high Andean region of South America is one of the few areas where soft, starchy-grained maize is produced and eaten. The conversion of these local maize types to a quality protein form is urgently needed, but progress has been, and will continue to be, slow, for three reasons. First, these very large grained types of maize have a long growing season in the high, cool environment of the Andes, and therefore it is possible to produce only one generation per year, compared with two or three in the normal breeding programme of tropical maize populations. Second, the grain, although much larger than opaque-2, has the same soft texture which is impossible to distinguish by eye. Chemical analysis for tryptophan or lysine of all selections is essential to determine if the quality protein is present. Third, crossing with opaque-2 reduces the grain size. It is necessary to select for large grain size as well as quality protein.

International maize breeding co-operation

The quality protein maize breeding programme is truly an international programme with breeding materials, populations and varieties being interchanged during the past three years between more than 31 different countries (see Table).

Another international trial that has provided interesting information about the performance of one quality protein hybrid is the International Maize Adaptation Nursery (IMAN) conducted by CIMMYT together with collaborators in 26 different countries. Amongst the 50 entries submitted from 18 countries for the first IMAN was the hybrid Agroceres 501, a commercial single-cross hybrid submitted by Agroceres in Brazil. This is an opaque-2 hybrid and it was the third most widely adapted entry with above average performance in Argentina, Brazil, Chile, Colombia, Ethiopia, Kenya, Mexico, Thailand, and Uganda.

The interchange of genetic material on this scale not only assists the breeders to develop widely adapted disease and pest resistant quality varieties, but it provides opportunities for local breeders in many different locations to test a very wide range of material for suitability to their local maize growing conditions. This approach is already stimulating the interest of several national maize programmes in quality protein maize for production by their local farmers.

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International Opaque-2 Maize Trials (I.O.M.T.) sent to different countries during the years 1970-1972.

| Country | First 1/ I.O.M.T. (1970) | Second 2/ I.O.M.T. (1971) | Third 3/ I.O.M.T. (1972) |
|---|---|---|---|
| Argentina | - | 1 | 1 |
| Brazil | 1 | 3 | 2 |
| Chile | - | 1 | 1 |
| Colombia | 1 | 2 | 6 |
| Costa Rica | 1 | 1 | - |
| Ecuador | - | - | 2 |
| Egypt | - | 1 | - |
| El Salvador | 1 | 1 | - |
| Ethiopia | - | - | 1 |
| FAO (Rome) | - | 1 | 10 4/ |
| Ghana | - | 1 | 1 |
| Guatemala | 1 | 1 | - |
| Honduras | 1 | 1 | - |
| India | 3 | 2 | 4 |
| Ivory Coast | - | - | 2 |
| Jamaica | - | 1 | 1 |
| Kenya | - | - | 2 |
| Malawi | - | - | 1 |
| Mexico (CIMMYT-INIA) | 4 | 4 | 7 |
| Nepal | - | - | 1 |
| Nicaragua | 1 | 1 | 1 |
| Nigeria | - | - | 3 |
| Pakistan | 1 | 1 | - |
| Panama | 1 | 1 | - |
| Peru | - | 2 | 2 |
| Philippines | 1 | 1 | 1 |
| Sri Lanka | - | - | 1 |
| Thailand | 1 | 1 | 1 |
| Uganda | - | - | 1 |
| U.S.A. | - | 1 | 1 |
| Venezuela | - | 1 | - |
| TOTAL | 18 | 30 | 53 |

1/ 30 Varieties received from 7 countries.

2/ 30 Varieties received from 6 countries.

3/ 30 Varieties received from 9 countries.

4/ For distribution to countries within the Near and Middle East.

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## Maize populations and varieties versus hybrids

CIMMYT has concentrated solely on the production of quality protein populations and varieties rather than hybrids because:

(a) A principal role of an international centre such as CIMMYT is to produce basic genetic materials from which scientists in co-operating countries can select varieties, or inbred lines for the production of hybrids, depending on whether or not there is an adequate seed industry within the country.

(b) CIMMYT believes from experience that a developing country should concentrate on varieties for its farmers, and not hybrids, unless there is a private seed industry that is capable of producing and selling high quality seed. In a number of cases, Governments have undertaken the seed production. However, there are few, if any, cases where Government sponsored seed production programmes have been successful. Government seed programmes producing hybrids, in general, have retarded advances in production rather than accelerated it.

(c) Farmers can maintain their own seed varieties and therefore there is no need for a highly sophisticated distribution and sales organization. This is particularly valuable in those developing countries with poorly developed transport systems and general lack of credit for buying seed.

(d) Varieties can be developed more rapidly than hybrids. By the time the breeding organization produces inbred lines, single crosses, and finally the hybrids are produced and increased and ready for sale, further improvement could have been made in the varieties so that the yield advantage normally assumed for hybrids is often lost.

(e) It is not generally recognized that it requires as many, or more, well qualified people to produce quality hybrid seed as it does to develop the hybrids. When sufficient numbers of qualified people are not available, a nation can ill afford to dissipate its resources for producing hybrid seed.

## Summary

The genetic and breeding programme in the period 1970-1973 has demonstrated that high yielding, vitreous, quality protein grain maize, incorporating desirable agronomic characteristics can be produced for a wide range of environments. The first population has been released - this is only a beginning. More will be required over the next few years to continue to improve the over-all characteristics, but also to serve

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to improve the agricultural and nutritive status in developing countries throughout the world where maize is an important crop. Rapid progress is being made towards the release of further superior populations for wide scale testing by the co-operating scientists from many countries.

It should always be remembered that breeding is a slow process, and the difficulties in this programme are accentuated by the need to use chemical analysis to identify the individual lines and seeds with high quality protein.

## Chemical and Nutritional Research and Analytical Service

### Quality markers

Early in the programme studies were made to try and identify any visible morphological or physiological characteristic of maize that may be of value as a "marker" associated with high quality protein. The opaque grain, expressed by the opaque-2 gene, was the only one, and it had two major deficiencies as a selection criterion. Firstly, it precluded any opportunity to obtain better hard endosperm grain types, and secondly, in opaque-grained populations it could not differentiate quality protein from normal protein lines.

### Chemical analysis

No alternative has yet been found for the identification of high lysine and tryptophan lines of maize other than by careful chemical analysis. To provide adequate selection procedure for breeding high quality protein maize several steps were required:

(a) A simple, rapid and inexpensive procedure for measuring the percentage protein in the endosperm and the amount of lysine and/or tryptophan in the endosperm protein of large numbers of small bulk samples of maize.

Studies and evaluations of a number of techniques for analyzing lysine and tryptophan in maize endosperm were carried out collaboratively in the CIMMYT Protein Quality Laboratory and the Biochemistry Laboratory of Purdue University (the latter financed by USAID).

Simple colorimetric techniques were developed for the analysis of percentage protein, lysine and tryptophan in maize endosperm from methods already published by other workers. These developments enable the laboratory technicians to handle large numbers of endosperm samples rapidly, and with the use of simple, inexpensive equipment. The techniques are simple to learn and the results are reproducible.

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Using the techniques for lysine and tryptophan analysis, it was found that, invariably, when an endosperm sample had high tryptophan values, it also had high lysine values in the protein. This information greatly simplified the screening of large numbers of maize families for the breeding programme. The screening was done by the simpler and more rapid tryptophan test, and only those samples found to have high tryptophan values were then checked for lysine content.

(b) A rapid technique for sampling the lysine and/or tryptophan content of the endosperm from single grains of maize without impairing its ability to germinate.

In certain cases, e.g., when one maize family with hard endosperm is identified as possessing high levels of tryptophan in the protein, it is necessary to analyze a subsample of single grains to identify whether there is a segregation within the family, and, if so, which grains have the high level of tryptophan. A technique was developed by the staff of CIMMYT Quality Protein Laboratory, whereby two or three small cores of endosperm are drilled out of a single grain without damaging the embryo. The minute quantity of endosperm is sufficient to analyze for tryptophan by a colorimetric technique. Those seeds having the high tryptophan values are then germinated in a greenhouse and eventually transplanted to the field for further genetic analysis and breeding. Without tests of this type, the rapid breeding progress so far achieved would not have been possible.

(c) A technique for establishing the amounts of all amino acids in a bulk sample with a high degree of accuracy.

Selected check samples, and the best of the material selected from the breeding programme are tested thoroughly for total amino acid pattern of their endosperm protein. A standard commercial automatic amino acid analyzer is used for this purpose. This procedure is necessary as a research tool, but practical breeding programmes do not require this expensive equipment, which requires frequent and highly sophisticated maintenance.

Using the above techniques, approximately 17,000 samples have been evaluated for protein, tryptophan and/or lysine from the CIMMYT genetic and breeding programme, and from programmes in 19 other countries including Argentina, Bolivia, Colombia, Honduras, Nicaragua, Peru, and countries in Africa and Asia.

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## Laboratory training

Because chemical analysis is the only method available to identify quality protein lines, assistance has been given to several countries in setting up their own analytical laboratories, and training personnel to man them.

Training has been provided as follows:

| Countries | Number of Trainees |
|---|---|
| Argentina | 1 |
| Colombia | 1 |
| El Salvador | 1 |
| India | 1 |
| Mexico | 5 (2 Ph.D., 1 M.S. students in Chapingo) |
| Nigeria | 1 |
| Pakistan | 1 |
| Peru | 1 |
| Philippines | 1 (Ph.D. student) |
| Thailand | 1 |
| United States of America | 1 (Ph.D. student Cornell University) |
| Venezuela | 1 |

## Biological assays

Research at CIMMYT indicates that maize grains need to have not only increased amounts of lysine and tryptophan, but also a proper balance of these amino acids to provide optimal nutritional value. To monitor this work a small animal nutrition laboratory was equipped during 1971. The test animal is the Meadow Vole (*Microtus pennsylvanicus*). Although a realatively new laboratory animal, the vole was chosen because it had special characteristics which enabled it to be used for relatively large scale screening of families and lines of high quality protein maize selected by the Protein Quality Laboratory tests. These characteristics include short reproductive cycle; reasonable litter size; short test feeding period; small quantity of test food per animal.

To test the vole for its suitability for maize quality selection, a co-operative animal test was conducted during 1972 to compare it with different laboratory animals. The tests were co-ordinated by CIMMYT and Purdue University. Several cereals were used as standard test samples, and these included 7 maize samples with representatives of normal and quality protein varieties with soft endosperm and one with hard endosperm.

The biological assays were conducted with rats, mice, voles, and small chicks. Tests were conducted with various of the above animals at Purdue University, INCAP, Guatemala; Nebraska State University;

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Washington State University; Manitoba University, Canada; and CIMMYT. These tests indicated that the vole was an unsatisfactory test animal because it was not possible to adequately separate the quality of several cereals and the variability between individual animals was very large.

Further tests are being concluded at present in which the composition of the diets is being varied to better suit the vole. If these tests are also unsatisfactory, the voles will be discarded in favour of rats. However, with their longer reproductive cycle and smaller litter size, coupled with larger test food requirement, the rats will not be able to be used as a screening animal, but will be used to test a smaller group of selected maize lines.

Recent work suggests that it may be possible to reduce the number of selected lines passing out of the Protein Quality Laboratory. Results indicate that a correct balance between the percentage protein in the endosperm, and the amount of lysine and tryptophan in that protein is more important than a large amount of either one. The breeders are now adjusting their selection criteria to produce lines with no less than 10 per cent protein and 4.0 per cent lysine in the protein. This will greatly reduce the number of samples required for nutritional study.

Eventually, when some of the selected lines are nearing time of release and there is sufficient seed, testing with swine and children will be undertaken. So far, as already mentioned, one hard endosperm quality protein line has been given provisional testing with swine and children. This testing is carried out with the collaboration of the International Center for Tropical Agriculture (CIAT) in Cali, Colombia.

## Latin American Developments

The original concept proposed by CIMMYT and approved by UNDP was to set up pilot projects in subsistence farming regions of Latin America to increase the production of maize by the introduction of a modern package of practices coupled with availability of fertilizers, credit, trained scientific advisory staff. When available from the research programme, new high yielding, quality protein maize varieties would be introduced to the project area to improve the diet of these farmers who eat their own produce.

### Programme initiation

At the outset, four CIMMYT staff members visited Bolivia, Colombia, and Peru at the request of the Governments to inform them about the Nutritive Maize Production Projects. A few weeks later, the Director General of CIMMYT and two staff members visited Colombia, Ecuador and Peru. The second visit to Colombia and Peru was to explore in detail the

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organization of NMPP's in those countries. A conference held in Puebla, Mexico, in August 1970 to discuss "strategies for increasing agricultural production on small holdings" was attended by political leaders, administrators, scientists and business men from 14 Central and South American countries.

As a result of these initial contacts with Governments in Latin America, five NMPP's have since been initiated, - two in Mexico and one each in Colombia, Honduras and Peru. Several other Governments have expressed interest in producing quality protein maize in their national maize production programmes.

Colombia:

In March 1970, the Agricultural Research Institute of Colombia (ICA) selected 10 scientists for training in Mexico. They were interviewed by a CIMMYT staff member and five of them were selected for two years training at the Graduate School, Chapingo, Mexico, and in the Puebla Project. Plan Puebla is a pilot project, which aims to demonstrate a method for doubling maize production and yields within five years among small holders in the rainfed area of Puebla, Mexico. It also seeks to train staff members who can serve this type of production project either in Mexico or in other countries.

To enable the project in Colombia to move ahead rapidly, five more scientists were given shorter, in-service training with the Puebla Project. Eighteen other scientists and agricultural leaders in the Colombian Ministry of Agriculture also visited the Puebla Project this first year. A detailed study was made by a Colombian scientist of four potential project areas. The final selection of the Oriente-Antioqueño region was made with the assistance of the CIMMYT staff.

There are approximately 35,600 farms in the region with an average size of about 5 hectares. The project team is initially concentrating its efforts on about one-third of the area, where the cropping pattern includes potatoes, maize and beans. The team is concerned with developing optimum production practices by agronomic research trials conducted on farmers' fields; marshalling the necessary credit and inputs, such as fertilizer; and then ensuring that as many farmers as possible are assisted to adopt the new technology through an extension programme. If it is assumed that at least three years of actual production are required to measure adoption rates and the impact on the region, it is too early to judge the success of this approach. The first meaningful evaluations will come at the end of 1974 and 1975.

The CIMMYT/UNDP-assisted project in Oriente Antioqueño region was the first to be set up, but it has stimulated a great deal of interest. Colombia now has the widest range of experiments in rural development of any Government in Latin America.

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Six projects are now in progress covering a variety of ecologies, and experimenting with a variety of methods. Ten to 14 more projects have already been approved by the Government. The six projects cover a total population of 1.9 million people, including 120,000 rural families. The project has so far touched only a small fraction of these people. However, the plan is ambitious and may eventually encompass 50 to 100 such rural development projects.

Three of the six projects are receiving foreign assistance, but only of a limited nature. The ICA employs all of the six project staffs - 100 project employees, including 40 college graduates - as part of its rural development programme. The Caja Agraria, a Government credit agency, has made an allocation of credit funds to each project area. All loans are contracted by Caja Agraria directly with the individual or community (for community projects), and the project staff only facilitate credit applications.

Dr. Canuto Cardona is Co-ordinator of the six projects, making arrangements for budgets, staff selection, staff training and inter-project contracts. He is employed by ICA, with funds supplied by CIMMYT from the UNDP Global One grant. Dr. Cardona is also the Director of the National Opaque-2 Maize Programme.

During 1972, Colombia grew between 700,000 to 800,000 hectares of maize, of which 25,000 hectares are of the opaque-2 type. This programme has been involved with: nutrition research in hospitals and one community near Medellin; industrial research in manufacturers' use of opaque-2 maize; home economics research on different methods of food preparation; health education campaigns; swine feeding trials on private farms; and production field trials of opaque-2 maize on 500 private farms. The grain type of the two maize hybrids used in the programme are of the soft endosperm type which is not favoured by the consumers. There is a need for a hard endosperm grain type, similar to the local commercial varieties. Only limited testing has so far been carried out of potentially useful quality protein maize varieties for the high Andean production projects. Although some have had acceptable yield levels, the grain type is unacceptable.

During the period 1970-1973 a total of seven Colombians have been, or are being trained for the M.S. degree at the Chapingo Graduate School and the Puebla Project. Twelve, including four sponsored by the International Development Research Centre of Canada, trained for shorter periods - averaging six months - in the Puebla Project.

The main input of CIMMYT in the future will be to: assist with training; assist with the initiation of a local training programme; continue to provide technical advice to the Government as required; provide germplasm and collaboration in regional and international breeding efforts, with particular emphasis on high altitude, high quality protein maize; and co-operate in biological assessment of quality protein maize germplasm.

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Peru:

Similar assistance is being provided by CIMMYT to Peru. After a study of four areas in the Sierra of Andes, the Cajamarca-La Libertad area, at an elevation of 2,000-3,200 metres, in a series of mountain valleys, was selected in December 1970 as the project area. About 220,000 hectares of crops and pastures are grown in the area, made up of wheat and barley, 54,000 hectares; maize, 42,000 hectares; potatoes, 20,000 hectares; all other crops 25,000 hectares; and the balance in pasture.

Out of Peru's 14 million people (1971), 6.5 million live in the Sierra and 600,000 in the Cajamarca project area. Hence the project is concerned with 5 per cent of the national population, and 10 per cent of the population of the Sierra.

Until the project was initiated, no fertilizer was available outside the capital city of Cajamarca, and no credit office existed outside the capital city; thus very little credit or fertilizer was used. No agricultural extension service existed in the project area before 1972.

All five professional staff of the project were trained in Mexico in 1971 on fellowships from UNDP/CIMMYT. These scientists were selected from eight nominated. Nineteen technicians have now been added to the staff.

During 1971, 74 maize experiments concerning variety evaluation and productivity were carried out; 85 wheat and 34 barley experiments were also conducted to obtain data about the multiple cropping system of the region. This number was extended during 1972. Some quality protein maize has been included in the experiments. However, varieties with high protein quality and very large soft grains of the type used in the area are not yet available from the breeding programme in Peru or at CIMMYT. Visits by CIMMYT technical staff occur several times a year.

The project is co-sponsored by: the National Agrarian University, La Molina, Lima; Directorate of Research, Peru Ministry of Agriculture; a regional credit bank for north east Peru; and CIMMYT. There were no adequate economic data on agriculture in this area when the project began. So far, the Government of Peru is spending about soles 3 million ($130,000) per year on the Cajamarca Project. The Ford Foundation is making a grant to the University to finance needed economic studies. It is hoped that the project will serve as a pattern for a series of similar projects to cover the entire Sierra region by the end of the 1970s. However, it is too early for evaluation.

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CIMMYT plans to continue its technical support through staff visits, training some extra staff and continued co-operation with the maize breeders at the National Agrarian University to breed the large, soft grained maize varieties with quality protein. Although progress is being made with this latter objective, it is slow as only one generation a year can be grown because of the long maturity period of this type of maize.

Honduras:

Two Government banks, the Banco Nacional de Fomento, and the Banco Central de Honduras, initiated a crop production programme patterned after the Puebla Project in early 1971 in the Francisco Morazán area of Honduras. It is an area with 15,000 hectares cultivated each year, principally to corn and beans. The area contains about 3,200 farmers.

CIMMYT agreed to assist the programme that was directed by an Honduran scientist trained at the Chapingo Graduate School, and in the Puebla Project, Mexico. The project staff totals six scientists, but the rest are young and relatively inexperienced. Because of this, CIMMYT has provided technical advice through staff visits, and in addition, has provided a staff member for a period of two months in 1971 and again in 1972, to assist with the planning, experimental site selections and planting of the experiments. Arrangements were made for two project agronomists to enter Tecnologico de Monterrey, Mexico, for further degree training in late 1972. They are being replaced by recent graduates from the Panamerican School of Agriculture.

The project began in 1971, a year devoted solely to placing trials and demonstrations of maize and beans on private farms in the valleys around the town of Cedros, 100 kilometres from Tegucigalpa. From the data obtained, a modified maize technology was recommended in 1972. This technology was to be applied to the improved variety available locally - CIMMYT Tuxpeño Synthetic. The recommendations were: fertilizer application, 60-60-0; plant population of 45,000 plants per hectare. These figures were based on performance from demonstration plots, not farmer average production. The demonstrated potential yield was 5.0 tons per hectare, compared to present acreage yields of 1.35 tons per hectare.

Yields did not come up to this potential in 1972 because of severe drought. At least three years of actual production experience will be needed to provide adequate evaluation of the project.

The two banks financing the project have agreed to continue their support for another year. They requested the project staff to initiate research on crop production in a second area, the Department of El Paraíso, during 1973. During 1973, the research staff was to move to the new area to develop the necessary technology to increase production. The extension staff will continue to spread the new technology in the original project area. By moving research staff it is hoped to reduce the cost of extending increased production to new areas.

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CIMMYT has been requested to continue to provide consulting visits by maize scientists, and to supply the projects with hard, flint, quality protein maize varieties as soon as they are available.

Mexico:

In early 1971, two Governors from the State of Mexico and Tlaxcala each decided, after seeing the Puebla Project, to initiate a maize production programme in their State.

State of Tlaxcala:

A small project to increase the maize production in the southern part of the State of Tlaxcala is being undertaken jointly by the State and Ministry of Agriculture (National Extension Service). The region has a total cultivated area of about 25,000 hectares. Some 70 per cent of this is planted to maize. There are approximately 10,000 farm families in the area.

There are four Mexican scientists employed by the State operating the programme. One Mexican member of CIMMYT staff is assigned to the project, and CIMMYT staff also are providing technical assistance in the organization and operation of the project, but no other support is provided.

During 1972, 972 farmers participated in the project with 2,300 hectares of maize managed according to the recommendations of the project staff. About three-fourths of these farmers were organized into 82 groups in 37 communities and were assisted in obtaining credit and inputs, such as fertilizer, for growing maize. An objective evaluation of yield on a sample of the farms of the participants was made just prior to the harvest. The estimated average maize yield for the 2,300 hectares was 2.4 tons per hectage.

Fifty-one agronomic trials involving varietal comparisons, rates of fertilization, time of applying nitrogen and phosphorus and levels of plant population were harvested in October-November 1972. The results of these experiments will be used to refine the recommendations for 1973. No quality protein maize has been used in this project, except in varietal trials.

State of Mexico:

The State Government approved a plan of operations and a budget of $160,000 for 1971 to initiate a "Plan Maíz". CIMMYT staff worked closely with state officials in organizing the programme. Twenty-two Mexican technical staff employed by the State have been assigned to the project; five of these staff are receiving, or have received, training in the Puebla Project.

The total cultivated area of corn is about 425,000 hectares. There are approxiamtely 150,000 farm families in the project area and their maize yield is about 1.2 tons per hectare. The Plan Maíz staff

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was able to reach 5,239 farmers in 1971 with both improved production practices and credit, and to assist 24,000 other farmers. In 1972, in general, climatic conditions were favourable for the production of maize and average yields continued to rise.

Two-hundred and eleven agronomic trials with maize were harvested during October-December 1972. These involved varietal comparisons, population densities, rates of fertilization and times of applying nitrogen. These data have been analyzed and the results used to refine recommendations on production practices of maize. To facilitate the use of this information by extension agents, a table of recommendations for each county has been prepared. An objective evaluation of maize production was made just prior to harvest and the results are:

Area devoted to maize with recommended practices.....63,568 hectares

Number of farmers concerned.....19,160

Number of farmers' groups..... 1,277

Number of "Planes Rancheros" a/... 32

Average Yield
Planes Rancheros..... 3.5 tons/ha.
State..... 1.9 tons/ha.

a/ Under each Regional Co-ordinator, several "Planes Rancheros", or farm programmes, were organized. Each Plan Ranchero is headed by an outstanding farmer of the area.

High quality protein maize from the National Institute of Agricultural Research (INIA) and CIMMYT are being tested in Plan Maíz. Although no varieties or hybrids with grain acceptable to the farmers for their own consumption has yet been produced, a pig-raising project with soft-grained opaque-2 maize is being tested. Every effort is being made to speed up the production of a flint type quality protein maize for this high altitude area. The long maturation period of these maize types is limiting progress to one generation a year.

CIMMYT is continuing to provide technical guidance with the field experiments. There is no financial support to this project from UNDP funds or from CIMMYT.

International meetings

The First International Seminar on Regional Rural Development Projects was held in Colombia on 10-18 September 1972. It was sponsored by the Instituto Colombiano Agropecuario (ICA) and the International Development Research Centre of Canada (IDRC). Approximately 30 field staff from the six regional programmes in Colombia, the Cajamarca-La Libertad Project in Peru, the Francisco Morazán Project in Honduras, and the State of Mexico, Tlaxcala and Puebla Projects in Mexico attended the Seminar. In addition, some 25 representatives of the Colombian Ministry of Agriculture, CIMMYT, CIAT, Ford Foundation, Rockefeller Foundation, International Development Research Centre, and the National Agricultural Research Institute of Ecuador were present.

The Seminar included general presentations by the Co-ordinators of the twelve regional programmes, visits to three of the Colombian programmes, and round table discussions of six major areas of activity in the regional programmes. A second seminar was to be held in Mexico in September 1973.

An International Symposium on Protein Quality in Maize was held at CIMMYT headquarters on 4-8 December 1972. It was sponsored by CIMMYT and Purdue University with financial assistance provided by the United States Agency for International Development, and the UNDP.

The Symposium was attended by 163 delegates from 41 countries. The programme included papers by 50 speakers from 11 countries. The topics were grouped into the sessions concerning nutritional studies on quality maize, and breeding for protein quality in maize. Sessions were also held on the commercial production of quality protein maize; chemical and biological evaluation of maize protein quality; economic implications of quality protein in maize, and progress in breeding for quality protein in other cereals. The proceedings of this Symposium are currently being edited for publication.

Summary

Under the influence of different political and economic environments, the above production projects have taken on various forms, but most are very different from the Puebla Project which stimulated the original interest. This progression is natural and encouraging. From it is growing a whole new technology of rural development, and hope for the large number of small peasant farmers.

Colombia provides the best example of this trend. The ICA has made an outstanding beginning with production projects. The project staff are well chosen and well trained; the projects are closely associated with the ICA research and top political support is being given to the programme of rural development. The Colombian projects are more accurately called rural development projects than agricultural production projects

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because they cover multi-crops and multi-animals, plus women's programmes and community institutions, including schools, public health campaigns and fertilizer outlets. A new national extension service is being built around these rural development projects.

Rural development projects such as these require a knowledge of credit administration, marketing, roads, schools, health practices, population growth and economic planning. These are broader skills than maize production which led CIMMYT to help organize the Puebla Project in 1966. These developments are attracting the interest and support of other assistance agencies such as the International Development Research Centre of Canada, the Ford Foundation and others, which can provide some of the required knowledge.

## THE FUTURE OUTLOOK

During the past few years, CIMMYT has gained considerable experience from its world-wide involvement in national maize and wheat programmes and by assisting with the initiation of five of the above-mentioned rural development programmes in four Latin American countries. This experience suggests that, to obtain the maximum increase in the production of quality protein maize on a world-wide scale, CIMMYT, with its limited scientific manpower, should concentrate its efforts by working through the national research and production agencies and programmes in the developing nations to increase maize production on a national scale. In this way the research and extension services essential for long term success and stability of a national quality protein maize programme can be developed.

Strengthened national maize programmes would stimulate and service both the broad-scale cultivation of quality maize, and they could provide the necessary technical support to rural development projects involving maize as one of the component crops.

### CIMMYT's role 1973-1976

Following the approval by the UNDP Governing Council at its fifteenth session, a new contract between UNDP and CIMMYT was signed on 13 March 1973 for Global Research on "Research and Training in the Development of High Quality Maize, Phase II". CIMMYT will continue the genetic research and breeding, and the chemical research and analysis at about the same pace as for the previous three years. The emphasis will be placed on the production of a diverse group of maize populations with wide adaptability, high yield, quality protein, pest resistance and acceptable grain types for use in various regions of the world.

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With maize of an acceptable grain type starting to be released from the breeding programme, CIMMYT is ready to move, during the next three years, to the next stage - world-wide use of quality protein maize in national production programmes. The geographic focus of the programme will be expanded from Latin America to include Africa and Asia.

Services offered to developing nations

Under the terms of the new project, CIMMYT will have the necessary flexibility to adapt its assistance and technology to the wide range of environmental, economic and technological conditions existing in different developing countries. Within the limits of its scientific manpower resources, CIMMYT can offer the following services to developing nations genuinely interested in developing, or increasing quality protein maize production through their national agricultural research and production organizations:

(a) Consulting visits by CIMMYT maize staff to assist with planning of a national quality protein maize programme; the staff structure necessary for its initiation and operation; a training schedule for staff development; a realistic budget; and periodic visits to assist Government and programme staff with the operational aspects of the national programme.

(b) Training fellowships. Approximately 20 fellowships per year will be available for in-service training with CIMMYT scientists in Mexico, or for Masters and Ph.D. degree training. In-service training is usually for a period of six to nine months. The subject areas are maize production, maize breeding, plant protection, and training in the Protein Quality Laboratory. The aim is always to select potential scientific leaders. The selection is normally carried out personally by a CIMMYT scientist.

(c) Provision of quality protein maize and normal maize germplasm from Mexico and the international breeding programme.

(d) Opportunities for national staff to participate in regional and international symposia and conferences related to quality protein maize research and production.

(e) Assistance to set up a small national quality protein service laboratory and train a chemist to operate it. This laboratory would be designed to assist the national maize breeders in their selection of quality protein maize varieties for local use.

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(f) Assistance with the establishment of national in-service training programmes to ensure maximum spread of the materials and technology as the national programme progresses.

A number of nations in Latin America, Africa and Asia are already collaborating with CIMMYT. For example all the Central American countries are linked together and to CIMMYT through the Central American Maize Co-operative. India, Indonesia, Nepal, Pakistan, the Philippines and Thailand are included in the Inter-Asian Corn Co-operative programme. This co-operative is also linked to CIMMYT for technical assitance and germplasm. Germplasm is interchanged with countries of the Near and Middle East through the FAO Near East Cereal Improvement and Production Project. Two sister organizations, the International Centre for Tropical Agriculture in Colombia (CIAT) and the International Institute of Tropical Agriculture (IITA) in Nigeria, have maize programmes operating co-operatively with CIMMYT.

CIMMYT has staff assigned to the following countries to assist their national maize programmes: Colombia (funds from UNDP); Egypt (Ford Foundation); Nepal (USAID); Pakistan (Ford Foundation); and, in collaboration with IITA, Tanzania (USAID and Ford Foundation); and, Zaire (Zaire Government).

CIMMYT believes that maximum benefit can accrue to the largest number of countries by the above approach. The potential for a large international effort is only because there are already many co-operative links involving CIMMYT with national programmes, and, more importantly, national programmes helping each other. CIMMYT's limited specialized resources of manpower can therefore be multiplied many times by the network of collaboration.