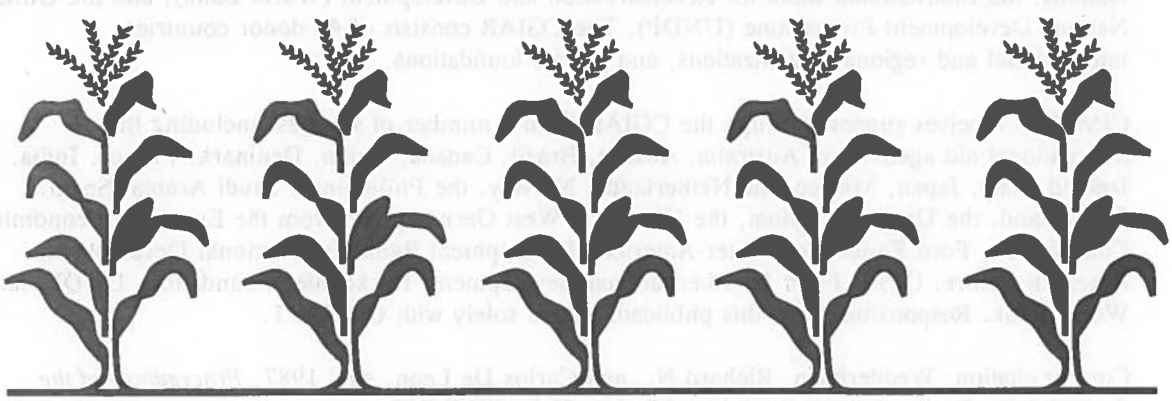
Proceedings of the Second Asian Regional Maize Workshop

Jakarta and East Java, Indonesia,
April 27 to May 3, 1986



Sponsored by Indonesia's Agency for Agricultural Research and Development (AARD) and the International Maize and Wheat Improvement Center (CIMMYT)

The International Maize and Wheat Improvement Center (CIMMYT) is an internationally funded, nonprofit scientific research and training organization. Headquartered in Mexico, the Center is engaged in a worldwide research program for maize, wheat, and triticale, with emphasis on food production in developing countries. It is one of 13 nonprofit international agricultural research and training centers supported by the Consultative Group on International Agricultural Research (CGIAR), which is sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). The CGIAR consists of 40 donor countries, international and regional organizations, and private foundations.

CIMMYT receives support through the CGIAR from a number of sources, including the international aid agencies of Australia, Austria, Brazil, Canada, China, Denmark, France, India, Ireland, Italy, Japan, Mexico, the Netherlands, Norway, the Philippines, Saudi Arabia, Spain, Switzerland, the United Kingdom, the USA, and West Germany and from the European Economic Commission, Ford Foundation, Inter-American Development Bank, International Development Research Centre, OPEC Fund for International Development, Rockefeller Foundation, UNDP, and World Bank. Responsibility for this publication rests solely with CIMMYT.

Correct citation: Wedderburn, Richard N., and Carlos De Leon, eds. 1987. *Proceedings of the Second Asian Regional Maize Workshop.* Mexico, D.F.:CIMMYT.

ISBN 968-6127-15-1

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Foreword

CIMMYT's Asian Regional Program is based largely upon one central conviction. namely that national maize programs can make more efficient use of their resources through research cooperation with neighboring countries. That conviction in turn assumes a set of common research challenges that can best be confronted by scientists from a number of countries working jointly toward solutions. In Asia this assumption is certainly borne out by the almost universal concern among maize researchers about downy mildew and by the success of their regional network in dealing with the problem.

In this region, as elsewhere, cooperation among national maize programs takes several forms (most frequently sharing of germplasm) but cannot exist in any form without continuous contact and frequent exchanges of information among maize researchers. CIMMYT regional staff promote and facilitate these exchanges in a number of ways, a very important one being participation in events like the Second Asian Regional Maize Workshop, which took place at various locations in Indonesia from April 27 to May 3, 1986, and included about 60 scientists from a dozen countries.

That workshop illustrated extremely well the various uses of such events in maintaining and strengthening the regional program. It was held some five years (too long a time) after the first regional workshop. During that period significant changes took place in Asian maize production (most notably a 50% increase in production, for which China and Thailand were mainly responsible), and the workshop provided researchers with an opportunity to take stock of the new situation and to consider its consequences.

Three features of the workshop's program strike me as having been particularly useful. First, participants spent a large share of their time getting to know the maize research program of Indonesia. They visited and heard presentations about research at the Muneng Research Station in East Java and also travelled to farmers' fields to observe and discuss the on-farm research program of the Malang Agricultural Research Institute for Food Crops. If these gatherings can be held more frequently, national scientists participating in regional activities will within a few years have a fairly detailed knowledge of the largest maize programs in the region.

Those scientists now have a good overview of maize breeding and research in some dozen countries as a result of a second feature of the workshop, namely the various means by which participants were encouraged to compare research approaches.

results. and products. One of those was a set of demonstration plots at the Muneng station. containing maize materials submitted by workshop participants. along with some CIMMYT varieties. The demonstration plots were an excellent way of familiarizing maize scientists with the best germplasm available in the region and gave them a chance to explore opportunities for germplasm exchange. This familiarity with one another's products was reenforced by country reports on each program's breeding and other research activities and by formal and informal discussions throughout the workshop.

A third feature of the workshop that also contributed materially to the regional program was the participation of representatives from several private seed companies, who gave presentations on their activities and included some of their products in the demonstration plots at Muneng. The program also included a visit to the seed production plant of the P.T. Bright Seed Company. followed by a tour of seed production fields in which an improved variety and hybrid are being grown under contract with farmers. At CIMMYT we consider this sort of contact between public and private sector maize workers to be vital in establishing the cooperative relationships we would like to see between the two sectors.

We hope that those and other features of the workshop were helpful to participants and that the publication of these proceedings will add to the value of the event. This document and the exchange of views it represents are highly beneficial to the CIMMYT Maize Program. For. the regional network in general and events like this workshop in particular are the most important link we have with national maize researchers and are our principal means of learning about their needs and concerns.

For the opportunity to gain a comprehensive view of maize research problems and activities in Asia, we are very grateful to all participants, especially our Indonesian colleagues with the Agency for Agricultural Research and Development (AARD). Central Research Institute for Food Crops (CRIFC), and Malang Research Institute for Food Crops (MARIF), who hosted this workshop and organized it jointly with CIMMYT.

R.P. Cantrell
Director
CIMMYT Maize Program

Acknowledgments

The success of the Second Asian Regional Maize Workshop was due to the efforts of various individuals, groups, and organizations. We would like to express our thanks for their contributions: first, to the participants for their enthusiastic support in supplying seed for the nurseries and preparing their country reports; to the Agency for Agricultural Research and Development (AARD) for giving us permission to hold the workshop in Indonesia; to the Central Research Institute for Food Crops (CRIFC) and Malang Research Institute for Food Crops (MARIF) for agreeing to co-host the workshop; to the steering committee under the chairmanship of the late Dr. B.H. Siwi, who was ably assisted by Drs. Sridodo Soetario and Subandi, for making the local arrangements; to P.T. Bright, Indonesia (especially Dr. Banjerd Boonsue, the local manager), for arranging a program for the delegates at the seed production facilities at Kediri, East Java; to Cargill Seed Indonesia for sponsoring a reception for the participants; to the hotels Orchid Jakarta and Karitika Wijaya Batu for the excellent accommodations, meals, conference facilities, and cultural entertainment; to the Dutch ATA team, notably Mr. Charles Van Santen, who worked to make sure things went well in East Java; the International Maize and Wheat Improvement Center (CIMMYT) for providing the financial support that made the workshop possible; and to the staff of the Muneng Research Station, who planted and took care of the demonstration nurseries.

In closing, we would like to express our gratitude for the contributions of the late Dr. B.H. Siwi, who passed away in February 1987. As chairman of the steering committee, he was a keen supporter of the workshop from its inception and worked diligently for its success.

Carlos De Leon
Richard N. Wedderburn
CIMMYT Asian Regional Maize Program

Opening Ceremonies

Welcome to the 2nd Asian Regional Maize Workshop

Gunawan Satari, Director General, Agency for Agricultural Research and Development, Ministry of Agriculture, Indonesia

It is with great pleasure that I welcome you to Indonesia and to this Second Asian Regional Maize Workshop, organized by the Agency for Agricultural Research and Development (AARD) and the International Maize and Wheat Improvement Center (CIMMYT).

Maize is an important crop in many countries of Asia and the Pacific. In 1981-83 the region produced 82 million t of maize, or about 20% of the world's total production, on 35 million ha, or 27% of the world's maize area. Yields in the region (averaging about 2.37 t/ha) were only about 73% of the world average, and in many countries they were 1.5 t/ha or less, far below the 5.8 t/ha achieved in developed countries.

In Indonesia maize is our second most important food crop. It is the staple food in many areas, including the island of Madura and parts of eastern Java. In an effort to increase maize production, the Indonesian government launched an intensification and extension program, as a result of which our maize production has increased from 2.73 million to 4.09 million t over the last 15 years, in spite of a slight decrease in the maize area. The rise in production was brought about by an increase in average yield from just 1 t/ha to the current level of 1.7 t/ha. The government has set a production target for 1988 of 6.01 million t to be produced on 3.23 million ha, implying a target yield level of 1.86 t/ha. It is urgent that we achieve those yield and production levels to satisfy the constantly increasing demand for maize to be used for human food, animal feed, seed, and other purposes.

Despite recent advances, maize yields in Indonesia are still low. If we can overcome various production constraints, however, it should be possible to raise yields markedly. Some of the technical constraints are drought, waterlogging, acid soils, and marginal land. Other complicating circumstances are that maize land and farmers' socioeconomic conditions in Indonesia are extremely variable. So that we can make more productive use of our resources, research should gradually be made more specific in terms of agroecology, socioeconomic factors, and maize use.

AARD has an active maize research program. Since 1980 we have developed and released six open-pollinated varieties, which have proved to be popular among farmers. Those varieties are resistant to the main disease in this region (downy mildew), are early maturing, and have high yield potential. We have also developed improved agronomic practices, pest and disease control methods, and farming systems, all of which contribute to higher and more stable yields.

Many problems can be solved only through a combination of research and the implementation of suitable policies. For example, to improve the quantity and quality of maize seed (which at present are inadequate), it is necessary to conduct research aimed at developing technology that will lengthen the storage life and improve the quality of seed. We must simultaneously develop a coordinated maize seed production and supply system. In the mixed economy of Indonesia, those efforts will inevitably involve, not only government institutions and cooperatives, but also the private sector.

Many farmers still have not adopted our improved varieties or do not achieve the yields possible with those varieties because they do not provide sufficient inputs of fertilizer and pest control measures. In addition, the improved varieties are not always suited to local agroclimatic and soil conditions. It will thus be necessary for our scientists to develop varieties that are better suited to specific agroecological zones, that yield well with low inputs of fertilizer, and are resistant to the major pests and diseases. At the same time, the extension services must make it clear to farmers that increased fertilizer applications and crop care are investments that pay off in terms of improved yields. The delivery systems for credit, seeds, fertilizers, and other inputs must be improved so that farmers will be able to take advantage of the new technology. Finally, the price of the output must be right, since only then will farmers be able to increase their maize production significantly.

Postharvest processing and marketing are other areas requiring increased attention from both researchers and the production-support system. New technology is needed to improve postharvest processing of maize, especially during the wet season, when a significant percentage of the harvest is lost because of poor drying and storage. Other requirements are new methods of processing maize for both human food and animal feed that prevent loss and wastage. Sufficient infrastructure--in terms of simple equipment, marketing facilities, and credit--must be made available to farmers so that they can take advantage of this technology.

During the last few years, we in Indonesia have begun to plant hybrid maize. The government has approved the release of four hybrids, which have been developed by private seed companies and by one of our leading universities. AARD scientists have cooperated closely in the development and testing of these maize hybrids. We welcome this type of cooperation between government scientists and the private sector.

Obviously, both hybrids and open-pollinated varieties have advantages and disadvantages. Although hybrids may offer higher yields, the seed is more expensive and may be scarce, and farmers must buy new seed each season. The best open-pollinated varieties, on the other hand, can give yields comparable to hybrids, and farmers can grow those varieties season after season from their own seed. Even so, farmers do have to buy new seed periodically, since a high-yielding variety can soon become contaminated by pollen from nearby stands of different varieties. I can therefore see a place for both open-pollinated varieties and hybrids. We must seek other low-cost alternatives for increasing maize production as well, evaluating all promising openings from genetic engineering to improved farming systems. There is much scope in those areas for valuable and productive research.

Success in this research will require better coordination of research workers both within and among countries. I am sure that in trying to promote such cooperation Indonesia and other countries could benefit from international efforts such as those of CIMMYT. Though its headquarters are located in Mexico, about half a world away from Jakarta, the Center has taken an active role in research on maize in Asia and the Pacific. Its staff have already made a great contribution toward increasing production of maize in our countries and towards improving the livelihoods of our farmers. We in Indonesia greatly appreciate the efforts that CIMMYT has made, and I am confident that we can further strengthen our ties to the benefit of our scientists and farmers. During this meeting I trust that we will have the opportunity to do just that.

The organizing committee has drawn up a tight program for these few days, and I am sure that you will feel somewhat tired at the end. Nevertheless, I hope that you will be able to appreciate some of the natural beauty of our country. I wish you again a pleasant stay in Indonesia and declare the Second Asian Regional Maize Workshop officially open.

Facilitating National Agricultural Research

Donald Winkelmann, Director General, CIMMYT, Mexico

It is a pleasure for CIMMYT and for me personally to participate in this Asian Regional Maize Workshop, with professionals from Pakistan on the west, the Philippines on the east, China on the north, and Indonesia on the south. I am most appreciative of the opportunity to talk with you for these few minutes about the Center's activities and about our commitments to the programs of the region.

Had we come together two decades ago, there would have been fewer of us, and on the average we would have been less experienced and less well trained. We would have had far fewer representatives from the private sector. Famine and scarcity would have motivated our deliberations, our major concern would have been the production of foodstuffs, and we would have made much of its maximization.

Time has changed all this. We at CIMMYT and you in your programs have new priorities, new resources, new agendas, and new ways to collaborate. Let me tell you about how we see that collaboration today.

Just a reminder about CIMMYT and the CGIAR system. The system is made up of some 45 donors and 13 international agricultural research centers, CIMMYT being one of these. The Center has about 100 professional staff members, roughly 35 of these in maize, with some 20 of that total operating in regional and bilateral programs outside of Mexico.

Our purpose is to facilitate the work of national agricultural research programs. While we are all, in the final analysis, concerned with farmers, CIMMYT's direct clients are the national programs. To them we provide improved germplasm, training, more efficient research procedures, information important to maize and wheat production, and counsel on the operation of maize, wheat and related economics research. We do not develop technologies for farmers; that is the task of national programs, who are in a far better position than we are to do so.

Like you, we live in a changing world. One important change is conceptual, relating to the role we see for agriculture in development. Two decades ago, and I am simplifying but only modestly, agriculture was seen largely as a source of inputs--labor and capital--which could be transferred at modest cost in terms of output to other parts of the economy, where they would contribute more directly to growth. Today, agriculture's role is seen differently. Through productivity growth, income flows to agriculture increase, thereby inducing an increase in agriculture's demand for goods and services, fueling continuing rounds of demand for products, including income elastic agricultural goods themselves. Some research shows that for every unit increase in incomes to farmers there are 1.5-2.5 units of added increase in the incomes of the rural communities that serve farmers. These are the flows we seek to stimulate though agricultural research and the resulting, productivity-increasing new technologies. But see how much more active this view makes agriculture's role. and notice its emphasis on the input--the productivity--side of the picture.

We are influenced by more operational changes as well. The IARCs and CIMMYT in particular are encouraged to undertake ever more collaborative research with advanced national programs, with the expectation that some research formerly in the portfolios of the IARCs will in the future be found in the portfolios of selected national programs. At the same time. the IARCs are being encouraged to move portions of their efforts upstream toward more basic research. And as a part of all of this, we are encouraged to watch more closely new developments in science. for example in biotechnology, so that we can take immediate advantage of developments that are relevant to our own work and ensure easy access to such developments for national programs.

Moving closer to regional programs. we are more concerned with the process of priority setting. First, we see advantages in being more explicit about our own priorities and will require more precise information about the priorities of our clients, the national programs. As well, we see advantage in national programs becoming more explicit in setting their own priorities. National programs in developing countries invest about US$2.5 billion annually in research. While this constitutes a great deal of resources, it is not large when compared with the opportunities for research and hence must be used as effectively as possible. This adds importance to the process of priority setting in national programs.

One thing we are doing in this context is to identify the characteristics of important maize-producing regions in each of the countries where maize is a significant crop. The results will give us a much stronger sense of the relative demands for our products. We will be seeking your help in this during the course of the week.

Let me add that one of the advantages of the on-farm research in which we are working with many of you is that this process too contributes greatly to an understanding of priorities for research.

And again with respect to priorities, much has been said about the importance of work in Africa. Our donors in the CGIAR have raised the priority for work there. We are responding positively through substantial increases in our staff there and with increased attention to themes of importance to maize in that region. But we are also quite conscious of the importance of maize in the Asian region. We recognize that this region includes some 45% of the maize grown in developing countries, with about 35 million hectares of the 80 million now under cultivation. We are cognizant of the importance of that maize and are adding to our staff so as to serve the region better. Virtually all of you know Drs. De Leon and Wedderburn of our regional maize program, many of you know Dr. Stevens, who works on maize with a bilateral program in Pakistan. You will soon come to know Dr. Gonzalo Granados, who is joining the Asian regional program, returning here after an absence of 15 years.

Now, what can we offer to the national programs of the region in the next few years? First, there will be a sharper focus on germplasm development and a more precise sense of where various classes of such materials can be utilized. Our offerings in training will be expanded to include: regional training programs, perhaps in conjunction with selected national programs having special skills in particular topics; in-country training efforts, especially in OFR; and a new program for midcareer visiting scientists who want to revitalize or reinforce their research skills. In addition, of course, the existing training activities will continue to function. We will hope to collaborate more actively with you in undertaking the analysis that contributes to the identification of priorities.

Finally, we see advantages in forming research networks focused on specific research themes of common interest. We will be talking more about these themes with you in the near future.

There is much to be done, new opinions to develop, new initiatives to launch. This workshop will help all of us to better understand those opportunities. My CIMMYT colleagues and I are pleased to be a part of this undertaking and optimistic about what can be done.

My thanks to you for coming and for giving so freely of your time. And my thanks, as well, to the AARD for the critical efforts in support of this workshop and for their choice of such congenial surroundings.

Country Reports: Production and Research
Malaysia

Lee Choo Kiang, Malaysian Agric. Research and Development Institute

Malaysia uses about a million metric tons of maize grain per annum, mainly as animal feed. Almost all of the maize consumed is imported, over 70% of it from Thailand, at a total cost of over US$120 million each year. To reduce these huge imports, which have grown at an annual rate of 10%, maize breeding and production research are being conducted in Malaysia to explore the possibility of producing the crop locally to meet some of the country's demand.

Background and Methods of the Breeding Program

Maize improvement in Malaysia has received continuous attention for the past two decades. The research branch of the Department of Agriculture and later the Malaysian Agricultural Research and Development Institute (MARDI) were actively involved in the Inter-Asian Corn Improvement Program from its inception in 1960 until 1975. MARDI continues to conduct maize improvement research with the active participation of CIMMYT's Asian Regional Maize Program.

Open-pollinated cultivars are widely used in Malaysia and are being developed through a program of population improvement that employs the following breeding methods: 1) mass selection, 2) modified half-sib selection, and 3) S_1 family selection. A program has also been initiated for producing hybrid maize. A combining ability study is being conducted with inbred lines at the S_5 level, the sources of which are CIMMYT's populations and cultivars introduced from Thailand.

Variety Testing and Release

MARDI has been quite active in carrying out variety trials with introduced materials. The results of multilocational trials conducted during the early 1980s showed that Suwan 1 C7, Across 7824, and Across 7728 are better in plant and ear height and yield just as well as MARDI Composite 1 C5 (Table 1). In trials conducted at Bertam, hybrids gave grain yields of more than 6 t/ha (in small plots) and had shorter, more uniform plant types than Suwan 1 C7, though this variety yielded just as well as the hybrids (Table 2). In other trials at Bertam, entries from Populations 28 and 31, Guarare 8328, Across 8328, San Cristobal 8328, Suwan 8328, and Farako-Ba (a) 8328 all gave yields exceeding 3.76 t/ha, with Iboperenda 8328 giving the lowest yield of only 2.74 t/ha (Table 3).

Table 1. Results of a multilocational variety trial

Cultivar	Grain yield (t/ha) Tal Tujuh	Pasir Putih	Pontiam	Bertam	Mean
Suwan 1 C7 F3	4.5	3.1	4.8	4.6	4.3
Suwan 11 C4 F3	3.9	2.3	2.9	3.4	3.1
Hycorn 9	4.4	-	2.9	4.2	3.8
Across 7824	4.5	3.4	3.2	4.7	4.0
MCI C5	4.4	3.0	2.7	-	3.4
Tocumen 7936	3.7	2.5	3.4	4.1	3.4
Caripeno DMR	3.7	2.5	4.0	-	3.5
Across 7728	4.4	3.2	-	4.0	3.9
LSD(0.05)	1.0	0.9	1.0	0.5	0.8

Table 2. Performance of hybrid maize at Bertam

Cultivar	Grain yield (t/ha)	Ear height (cm)
2H 106	6.6 a	89.0 b
2H 107	6.5 a	89.1 b
P 6181	6.3 a	95.4 ab
Suwan 1	5.9 ab	99.9 a
XCF 34	5.4 b	82.3 c
3H 001	5.3 b	82.3 c
CV (%)	9.5	7.1

Table 3. Results of a CIMMYT trial of full-season varieties at Bertram, 1985

Entry	Grain yield (t/ha)	Ear height (cm)
Guarare 8328	3.86 a	98.9 abcd
Across 8328	3.79 a	106.4 abcd
San Cristobal 8328	3.79 a	102.4 abcd
Suwan 8328	3.76 a	111.3 ab
Farako-Ba (a) 8328	3.78 a	110.7 abc
San Cristobal (1) 8328	3.52 ab	100.9 abcd
Farako-Ba 8328	3.04 abcd	99.9 abcd
Suwan 1 C7	3.25 abc	91.8 def
Iboperenda 8328	2.74 bcd	112.2 a

Since maize has not traditionally been grown for grain production in Malaysia. MARDI has released no cultivars for grain production over the past ten years. although two cultivars. MARDI Composite 1 C5 and Suwan 1 C7 have been endorsed for planting. The former is a full-season cultivar adapted to the humid tropics; it tassels at 50 days and matures at 105 days. Since its endorsement. however, this cultivar has been replaced by an introduction from Thailand. Suwan 1 C7. which has shorter plant height and cob placement. The latter cultivar has undergone five cycles of modified half-sib selection. and superior half-sib families have been composited into an experimental variety designated MMI C5.

Pilot Project for Maize Grain Production

As mentioned above. Malaysia has no tradition of maize grain production. To explore the possibilities of establishing production, a pilot study has been initiated by MARDI. Since the cost of labor is high in Malaysia, the study is examining completely mechanized maize production (from land preparation and planting to weed control and combine harvesting). which reduces the costs of the operation to about US$300/ha, compared to an estimated cost of US$400/ha with manual labor.

Grain yields in this study have been low. averaging 2.5 t/ha in a trial conducted at Bertam. At the current price for maize of US$130/t. the return is just enough to cover production costs. In certain areas. however. that have better soils. yields could reach 3.9 t/ha. and we project that with continuous cultivation and soil amendments (especially liming to correct low soil pH) grain yield can be much improved.

This study will be continued at Bertam and is being expanded to include a 25-ha site at Permatang Pauh. Its outcome is likely to have an impact on maize production policy in Malaysia. If it is shown that maize grain can be produced profitably in the country. vast areas of currently unused land (particularly the estimated 160.000 ha on which rice was cultivated previously) could be brought back into agricultural production.

Seed Production

If maize production does take hold in Malaysia. production of seed is unlikely to be a problem. Pioneer Hybrid International has already given marketing rights to a local enterprise for selling Pioneer hybrid seed. Moreover. the Department of Agriculture has a modern seed processing plant at Titi Gantong. Perak. that would be able to supply seed of open-pollinated cultivars.

Sweet Corn Breeding
Malaysian farmers grow some 4000 ha of sweet corn annually to meet demand in the market for green maize. Two traditional cultivars. Local Flint and KB_1 (a sweet corn) have been completely replaced by Thai Supersweet. which was introduced by MARDI. The Institute has initiated population improvement in that material and selected two populations. Supersweet Kuning and Supersweet Merah. which have reduced plant and ear heights and increased ear size and are characterized by yellow and red kernels. Both populations are being tested for yield at the farm level.

MARDI has also introduced brittle-1 sweet corn materials from Hawaii and Taiwan. Those materials are undergoing population improvement and being crossed to local maize to improve their adaptation and disease tolerance. Introduced materials respond to our humid tropical climate by tasseling too early (at 45 days) and showing reduced plant height, which results in smaller ears.

Discussion
J.M. Corpuz: What is the objective of your mulilocational tesing? What programs or mechanisms do you have for disseminating research results to farmers?

Lee Choo Kiang: Multilocational trials are conducted to determine the adaptation of varieties and soil fertility status for maize production. We have a division that specializes in transferring technology to farmers.

Gonzalo Granados: From your presention it is evident that it is not economic to grow maize in Malaysia; the costs per hectare are higher than the value of the maize produced. Could you please elaborate?

Lee Choo Kiang: With mechanization and recommended inputs. we can break even at the present low price of maize. With continous soil improvement. however. we expect that yield will increase to about 4 t/ha. Moreover, any price increase in the future will be an added bonus for the producer. Policies that would permit production of maize on abandoned rice land are also relevant to this issue. Maize production could be subsidized. as is rice (at US$70/t), to encourage production and save foreign exchange.

R.P. Bosshart: For testing of hybrids, what fertilizer rates (average and highest) were used at each of your four variety testing locations, and what were the plant populations at harvest? Were plots irrigated?

Lee Choo Kiang: Fertilizer rates were 120 kg N, 60 kg P_2O_5, and 40 kg K_2O at all four locations. Plant populations were 53,000 plants per hectare at sowing and from 30,000 to 40,000 at harvest. The trials were not irrigated. In the grain production study, fertilizer rates were 120 kg N, 60 kg P_2O_5, and 40 kg K_2O. Plant density was 53,000 plants per hectare at sowing. The experiment was not irrigated, although we are considering a raingun system for a future study.

Joginder Singh: Do you have any problems with storage and germination of Super Sweet?

Lee Choo Kiang: To avoid storage problems, we keep seed in open rooms for only 3 months, in air-conditioned rooms (20^oC) for 6 months, and in refrigerators (5^oC) for 12 months.

Chamnan Chutkaew: When do you expect to release hybrid sweet corn? What germplasm in your program seems most promising?

Lee Choo Kiang: In hybrid sweet corn development, we are at the S_4 stage of inbreeding with lines extracted from Thai Supersweet. Since it is impossible to say what degree of hybrid vigor we will observe, we cannot yet predict when our hybrid sweet corn will be released. Supersweet Yellow and Supersweet Red are better than the original Thai Supersweet. No superior material is available yet for grain production.

Charas Kitbamroong: What is the effect of the brittle-1 gene in Hawaii Supersweet? How do you measure this effect in your program?

Lee Choo Kiang: Hawaiian Supersweet 9 with the brittle-1 gene is sweeter than Thai Supersweet with the shrunken-2 gene and sweeter than Hawaiian Supersweet 6. The difference in sweetness between the brittle-1 and shrunken-2 genes is measured by taste panel.

K.K. Lal: What is maize used for in Malaysia? Do you have problems with cob borers in sweet corn?

Lee Choo Kiang: All the maize we import is used in chicken and pig production. Cob borers can be a serious problem, depending on the season, and sometimes must be controlled with insecticide sprays.

Sri Lanka

C.B. Hindagala, Office of Deputy Director, Agriculture (Research)

Maize is the second most important cereal crop in Sri Lanka. It is used mainly as a feed grain for poultry, though a considerable amount is also used as food. Maize cultivation is confined largely to the highlands of an area generally referred to as the dry zone, where shifting cultivation is still the predominant type of agriculture. Rainfall distribution in the dry zone shows a bimodal pattern in which two well-defined rainy seasons can be identified. The major rainy (maha) season extends from early October to late January, during which time about 880 mm of rainfall are received. The dry (yala) season, with about 400 mm of rainfall, starts in late March and lasts until late July. Maize is cultivated during the rainy season, sometimes as a monocrop, but more commonly in a mixed cropping pattern with cowpea, finger millet, or vegetables.

Production Constraints

From 1976 to 1985, the extent of the area planted to maize increased by 23% and production by 17%, while the average yield dropped by 5% to 977 kg/ha, which is very low compared to the yield potential of currently available varieties (Table 1). Limited use of high-yielding varieties and fertilizer is the main reason for low yields, though production is limited by numerous other factors, which can be divided into five categories: 1) physical, 2) biological, 3) socioeconomic, 4) marketing, and 5) seed production.

Table 1. Cultivated area, production, and yield of maize in Sri Lanka, 1976-85

Year	Area (ha)	Production (000 t)	Yield (kg/ha)
1976	30,409	31.19	1026
1977	36,758	41.99	1142
1978	28,634	33.80	1180
1979	23,494	25.76	1096
1980	24,789	31.50	1271
1981	27,465	34.65	1262
1982	34,137	38.67	1133
1983	47,276	51.07	1080
1984	43,084	39.08	907
1985	37,244	36.40	977

Source: Department of Agriculture.

Physical constraints--During the rainy season, undesirable physical properties of the soil pose problems in tillage if the land is not prepared at the correct time and correct moisture status. Timely planting is possible if tractors are used for land preparation, but most farmers cannot afford to do so. Another problem is sealing of the soil surface as a result of heavy rains followed by dry weather, a condition that commonly occurs in reddish brown soils and leads to poor seedling emergence. Since maize is grown under rainfed conditions, it is also under considerable risk of damage from excessive moisture or, more commonly, drought.

Biological constraints--Heavy weed growth is among the many biological factors that reduce yields. It is a difficult problem to control since heavy rains interfere with mechanical weeding and farmers are often unable to use costly herbicides for maize.

Stem borer (Chilo partellus) is a serious threat to maize cultivated during the dry season. Data collected by the entomology division of the Maha Illuppallama agricultural research station show that stem borer populations fall to a minimum from September to November but rise to a very high peak from February to April.

At present chemicals offer the only means of controlling this pest but can be very expensive. Maize is also highly susceptible to attack by storage insects, whose damage results in rapid deterioration of seed.

The most common diseases affecting maize in Sri Lanka are stalk rots and banded leaf and sheath spot, which appear to have increased in severity during the last few years. Incidence of bird damage has also been high.

Socioeconomic constraints--Maize is grown by subsistence farmers in a system of shifting cultivation that gives low marginal returns. Since farmers often do not own the land they cultivate, they have little incentive to adopt soil conservation measures and other practices that would maintain soil fertility. They also lack the financial resources to buy necessary inputs such as fertilizer and seeds, nor is credit available for such purchases. Though the government has organized credit schemes through the banks, farmers engaged in rainfed agriculture are reluctant to take advantage of these services because of the high degree of risk involved in their farming operations.

Marketing constraints--Although maize can be sold to government purchasing centers at a guaranteed price of Rs. 4000 (US$144)/t, most of the harvest is purchased by private traders at a lower price. The reasons are several: 1) private traders give farmers immediate cash payments. 2) private traders impose no strict grading or quality standards, and 3) since most maize areas are located far from the purchasing centers, farmers must, for lack of transport, sell their produce to the private middlemen, who take advantage of the situation.

Seed production constraints--Inadequate supply of high-quality seed is also an important limiting factor in production. The Department of Agriculture is the main supplier of seed, which is produced on government farms. In 1985 a total of 37,000 kg of seed were distributed, an amount which fell short of the requirement. Among the chief reasons for insufficient seed supplies is a lack of qualified personnel and facilities for seed production, processing, and storage. What commonly occurs is that seed produced in the main season must be stored for about eight months before planting, and loses its viability as a result of poor storage conditions.

Early Maize Studies

The need for improvement of maize production in Sri Lanka was realized in the early 1950s, and the task of conducting research for that purpose was entrusted to the Regional Agricultural Research Center at Maha Illuppallama. Because of the country's diverse climate and soils, however, research was decentralized and now takes place in eight agroecological zones, each of which has a regional research center and substations for conducting trials. Maize research is currently conducted at five stations, with Maha Illuppallama as the main center.

Early maize research focused mainly on varietal improvement and led to the release of the country's first improved open-pollinated variety (T-48) in the early 1960s. At that time attempts were also made to develop hybrids locally, using conventional inbred line techniques. Yields of the best hybrids, however, were not high enough to warrant release of those materials. More encouraging results were obtained with varietal hybrids, which were developed by crossing selected varieties and proved to be easier and cheaper to produce. The best varietal hybrid (Veracruz 181 x Antigua 2-1A x local variety) gave a yield of 6540 kg/ha, 38% higher than that of T-48. This work was not continued, however, because there were no organizations in Sri Lanka that could handle production of hybrid seed and it was realized that, if farmers did not also adopt improved management practices, the hybrids might not have any impact on production.

Variety Improvement

Once it became clear that hybrids were not a practicable option, emphasis was redirected toward development of open-pollinated varieties, with the following objectives: 1) high yield potential and wide adaptability, 2) full-season materials maturing in 110-115 days and early to intermediate varieties maturing in 90-100 days; 3) shorter plant types with good husk cover. 4) resistance to stalk rots and banded leaf and sheath spot. 5) drought tolerance, and 6) acceptable grain type (preferably yellow/orange flint).

Thai Composite--Establishment of close links with CIMMYT and the Inter-Asian Corn Improvement Program created a regular flow of improved germplasm into our breeding program, starting in 1970 with Thai Composite, which was introduced from Thailand. When this material was first tested at Maha Illuppallama in 1971, it gave a slightly lower yield than T-48 but responded well to selection. A variety developed from Thai Composite yielded 23% more than T-48 in multilocational trials conducted from 1974 to 1977 (Table 2). It was released by the Department of Agriculture in 1977 under the name Bhadra-1 and has since become popular among farmers.

New varieties--Work is in progress on several new varieties. A composite formed by combining Bhadra-1, Cupurico x Flint Compuesto, and Poza Rica 7425 showed promise in multilocational trials conducted from 1981 to 1985, yielding 10% more than Bhadra-1. Other varieties gave yields 9-16% higher than that of Bhadra-1 in multilocational trials conducted during the rainy season of 1984-85 and will undergo further testing.

Table 2. Performance of maize varieties at four locations, 1974-75 rainy season, and at seven locations, 1975-76 and 1976-77

Variety	Grain yield (kg/ha) 1974-75	1975-76	1976-77	Mean
Bhadra-1	4724	3912	4116	4250
Cupurico x Flint Compuesto	4031	3932	4109	4024
Local variety (Check 1)	--	2698	--	2698
T-48 (Check 2)	3493	3394	3466	3451

White maize--Although most of the maize grown in Sri Lanka has yellow grain. there is also a limited demand for white maize. Two white-grain varieties (Across 7929 and Across 8043) have been identified that possess higher yield potential than Bhadra-1 (Table 3).

Early maturing varieties--Varieties that mature in 90-100 days are required for cultivation during the rainy season when planting is delayed owing to late rains and are also suitable for planting in the dry season. In trials conducted during the rainy season of 1983-84 and 1984-85 at Girandurukotte, Poza Rica 7931 gave the highest yield of the eight early maturing varieties tested and was about a week earlier in flowering than Bhadra-1, which is a full-season variety (Table 4). Some of the early maturing varieties are being further tested in multilocational trials.

Table 3. Performance of maize varieties at five locations[a], rainy season 1984-85

Variety	Grain yield (kg/ha) 1	2	3	4	5	Mean[b]
Across 7929[c]	3157	6515	8542	4007	3417	5128 (116)
Guarare (1) 8128	2538	6285	8395	4359	3689	5053 (114)
Poza Rica 8136	2913	6312	9298	3929	2722	5035 (114)
Across 8043[c]	2525	6769	7783	4133	3110	4864 (110)
Los Banos 8136	2532	6058	7959	4429	3319	4859 (110)
La Molina 8128	2583	6387	7532	4716	3016	4847 (109)
Ferke (1) 8128	2996	6485	7529	3992	3173	4835 (109)
Composite-6	3027	6174	8480	3783	2684	4830 (109)
Local Varietal Composite-1	2920	5965	7645	3375	2554	4492 (101)
Epolgama x Across 7843	2888	4712	8169	3418	2971	4432 (100)
Bhadra-1 (Check)	2610	6318	7215	3783	2213	4428
C.V. (%)	20.0	7.9	15.9	18.2	16.0	
LSD (P = 0.05)	557	837	N.S.	N.S.	689	

[a] 1 = Maha Illuppallama; 2 = Girandurukotte; 3 = Aralaganwila; 4 = Moneragala; and 5 = Karadian-Aru.

[b] Figures in parentheses indicate percentage of check yield (Bhadra-1).

[c] Variety with white grain.

Quality protein maize--Several quality protein maize varieties obtained from CIMMYT have been tested and may be suitable for areas of Sri Lanka where maize is part of the human diet. Poza Rica 8140 and Across 8140 have given slightly higher yields than Bhadra-1, a normal variety (Table 5).

Table 4. Mean yield of eight early maturing maize varieties, Girandurukotte, rainy season 1983-84 and 1984-85

Variety	Yield (kg/ha)
Poza Rica 7931	4401
Tocumen 7931	4267
Pirsabak 7930	4274
Arun-2	4215
Ranjuna	4102
Thai Comp I Early DMR (S) C4	3723
Early DMR Comp 2	3593
Early DMR Comp 1	3510
Bhadra-1[a]	5120

[a] Full-season variety.

Table 5. Performance of nine quality protein maize varieties, Experimental Variety Trial 15A, Maha Illuppallama and Girandurukotte, rainy season 1983-84

Variety	Grain yield (kg/ha) Maha-Illuppallama	Giranduru-kotte	Mean
Poza Rica 8140	3472	5366	4419
Across 8140	3785	4956	4371
Across 7940 RE	3160	4830	3995
San Jeronimo 8140	2986	4577	3782
San Jeronimo (1) 8140	3333	4135	3734
San Jeronimo 8039	3125	4325	3725
Across 8039	3021	4325	3725
Los Banos 8140	3090	4198	3644
Pichlingue 8039	2153	3851	3002
Across 7726 NRE	2326	4135	3231
Bhadra-1 (Check)	2778	5177	3978
LSD (P = 0.05)	1012	887	
C.V. (%)	23.5	13.3	

Indigenous maize varieties--A considerable part of Sri Lanka's maize area is planted to indigenous varieties. Almost all are flint types, but they differ in grain color and maturity. Most are tall, leafy, and late maturing, tend to lodge at normal plant densities, and generally yield less than improved varieties.

The prevailing practice among farmers of selecting maize seed for the following season within a small maize population in each field may have led to steady inbreeding within the indigenous maize varieties, particularly where a single variety has been grown in a field and fields are far apart. Where different varieties have been grown on adjacent fields, natural hybridization over the years has probably eliminated all traces of the original varieties. As a result, one can expect indigenous maize varieties to be highly mixed or inbred (Sithamparanathan 1958).

Through selection by farmers over a long period, indigenous varieties have acquired resistance or tolerance to various stresses, such as drought, pests, and diseases. To retain any desirable characters that might be found in those varieties, a population was formed by combining indigenous varieties collected from different maize-growing areas. Other more promising varieties, including Bhadra-1, Capurico x Flint Compuesto, and Across 7843 were also incorporated into this population, which is now undergoing improvement.

Agronomic Investigations

Fertilizer rates--As mentioned previously, maize is generally grown in a system of shifting cultivation in the highlands of the dry zone. Farmers cultivate the land for two or three seasons after clearing the jungle and then abandon it. The soils of these newly cleared lands (chenas) have a good enough supply of nutrients that it may not be necessary to use any fertilizers for the first few seasons. As land for shifting cultivation becomes more scarce, however, farmers will have to adopt a more stable type of cultivation on the rainfed highlands. When such a system is adopted, the fertility status of the soils will decline rapidly, and use of fertilizer will become important for maintaining yield levels.

Most of the soils in the highlands of the dry zone are reddish brown soils. These sandy clay loams are slightly acid to neutral and low in agronomic matter, nitrogen, and available phosphorous. Potassium is present in fair amounts, however. Several fertilizer experiments were carried out to determine the optimum rate of NPK fertilizer. The economical rate for most areas was found to be 70 kg N, 45 kg P_2O_5, and 30 kg K_2O/ha.

Fertilizer management--A system designed to permit continuous cropping in rainfed uplands was established under simulated forest conditions in 1977 (Handawela 1985). A stand of trees (Gliricidia maculata) was planted in one block with spacing of 2 x 6 m, while the adjacent block was left bare. The purpose of the tree stand was to reduce erosion, increase the level of soil organic matter, fix nitrogen, recycle nutrients, and reduce weed growth. Cuttings from the trees were applied to the fields of the simulated forest, and the crop and weed residues were left on both the forest and bare plots.

A maize experiment was conducted on those fields during the 1983-84 maha season to study the effect of five levels of nitrogen. The results show that in the simulated forest 0- and low-nitrogen (30 kg/ha) treatments gave higher yields than the corresponding treatments in the bare field. With higher levels of nitrogen, however, yield differences between the fields were less apparent.

Plant density--Studies conducted at research stations and in farmers' fields, with different fertilizer rates and local and improved varieties, led to the following plant density recommendations: 1) assuming adequate amounts of fertilizer and moisture, 55,000 plant/ha (60 x 60 cm, two plants per hill) is best for grain production with improved varieties such as Bhadra-1; 2) tall, leafy local varieties should be grown at lower densities, i.e., 37,000 plants/ha (60 x 45 cm, one plant per hill) to prevent lodging and poor ear development; and 3) plant density should be reduced at low fertilizer levels or when none is applied.

Weed control--In shifting cultivation the incidence of weeds is minimal, so farmers practice almost no weed control. As cropping frequency increases beyond two or three seasons, however, there is a progressive build-up of weeds. Initially, the weed flora comprise both broadleaves and grasses, but as cultivation continues for more than six or seven years, the grass weeds, both perennial and annual types, become predominant. On continuously cropped land, heavy weed growth can reduce yields by 30-40%.

In shifting cultivation, a minimum amount of tillage (such as scraping the soil) is sufficient to obtain a weed-free seedbed. On continuously cropped land, however, more intensive land preparation (plowing, followed by one or two harrowings) has to be done to minimize weed growth. Only a few farmers can afford these operations, though, and they are not using any herbicides for maize, although studies indicate that atrazine (applied pre-emergence) gives effective control of weeds in maize.

Water requirements and irrigation--During the rainy season, there is a 75% probability that rainfall alone will satisfy the water requirement of a 120-day cereal crop like maize (Panabokke and Walgama 1974). During the dry season, however, the chances of obtaining a good crop of maize under rainfed conditions are quite low, and the crop must be irrigated during dry periods. Most of the 300-400 mm of rainfall received during that period falls in April. The dry season is characterized by high temperatures (with average maximum and minimum temperatures of 34°C and 24°C, respectively, with relative humidity of around 80%) and strong dry winds with speeds of nearly 165 km per day for the season. The class A pan evaporation rates are also high, exceeding 5-6 mm per day on some days.

The reddish brown soils have a narrow range of available moisture. The average moisture content at field capacity is about 20% (W/W) and at permanent wilting point is 10% (W/W). Thus, the amount of available moisture per meter of soil is 135 mm, and about 85% of the available moisture is released at a tension of one atmosphere.

The total water requirement of a 115-day maize crop during the dry season at Maha Illuppallama was found to be 615 mm. Maize yields decreased significantly when the crop was irrigated at a level below 50% depletion of available soil moisture. When irrigated at 50% depletion of available moisture, the crop yielded 4100 kg/ha, and at 75% depletion yield dropped to 2226 kg/ha. Under adverse weather and soil conditions, it appears that maize has to be irrigated at least once every three or four days to prevent moisture stress during dry periods of the dry season.

On-Going and Planned Research

Breeding--In addition to the work on open-pollinated varieties, a new program will be initiated to develop hybrids for possible use in the future. An important priority of the open-pollinated variety effort will be to reduce plant height. For that purpose a population was developed by combining a short local variety with an introduction from CIMMYT (Epologama x Across 7843). This population is now undergoing improvement. Other tasks of the breeding program will be to select for drought tolerance and develop resistance to stalk rots and banded leaf and sheath spot.

Agronomic investigations--These will include studies conducted in farmers' fields to determine economic levels of fertilizer, efforts to find efficient methods of fertilizer application to reduce waste and loss, and investigations of intercropping, "avenue" cropping (in which leguminous trees such as Leucaena leucocephala and Gliricidia maculata are used to improve the physical, biological, and chemical properties of the soil), simple, inexpensive weed control methods, irrigation, and crop storage.

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Discussion

M.Q. Chatha: You mentioned the utilization of quality protein maize in regions where maize is mostly used for food. Have you prepared a concrete plan for popularizing quality protein maize in Sri Lanka? If so when will you begin utilizing this maize on a large scale, and how have you planned to solve the problem of isolating and maintaining quality protein maize.

C.B. Hindagala: Quality protein maize is still in the experimental stage in Sri Lanka, so we have not yet planned a production program.

Joginder Singh: Have you identified a good source of resistance to banded leaf and sheath spot? What are some of the companion crops of maize in the mixed cropping systems you mentioned? Have you tried to select varieties for intercropping systems? How is the expression of kernel vitreosity in two of the opaque-2 varieties (Poza Rica 8140 and Across 8140) that seem to have done well in your country?

C.B. Hindagala: We have not yet identified good sources of resistance to the leaf and sheath spot disease. Farmers generally intercrop maize with pulse crops, vegetables, or finger millet. We have carried out intercropping studies with maize and cowpea, green gram, black grain, soybean, groundnut, and chillies. The results indicate that soybean is good for intercropping with maize. We are not selecting varieties for intercropping systems. The two opaque-2 varieties show good expression of vitreosity.

S.J. Patil: With such high rainfall during the rainy season (800 mm in a period of four to five months), how do you explain the absence of major diseases such as leaf blight and downy mildew?

C.B. Hindagala: The most important diseases of maize in Sri Lanka are stalk rots and leaf and sheath blight. We have also observed leaf blights and curvularia leaf spot in some of the introduced and local varieties but no downy mildew. Our pathologist is doing a survey in the maize-growing regions to identify and determine the importance of any other diseases that affect maize.

M. Afzal: Why is there so much variation between years in the yield of the same variety?

C.B. Hindagala: The main cause of these differences is variation in climate. particularly rainfall. Our maize variety trials are grown under rainfed conditions.

E.J. Stevens: Why did yields drop between 1981 and 1985? What is the number of days to anthesis and to maturity of Pirsabak 7930?

C.B. Hindagala: The drop in yield can be attributed mainly to variation in rainfall. Pirsabak 7930 takes about 45 days to reach 50% silking and about 90 days to mature.

China

Li Jingxiong, Institute of Crop Breeding and Cultivation, Chinese Academy of Agricultural Sciences

Trends in Maize Production

Since the early 1950s, China has become the second largest maize producer in the world, with 16.2% of the total area planted to maize, 18.6% of the output, and 114.2% of the average yield in 1983. Within the Asian region, excluding the Middle Eastern countries, the corresponding figures for China were 54.4%, 73.3%, and 156.3%, respectively. Maize production grew steadily in China during 1970-1984. Output and yield curves rose steeply along parallel paths, reaching their respective plateaus at 73.3 million tons and 3.96 t/ha in 1984. Within the last four years, however, those record high figures were accompanied by declining area planted to maize.

The increase in maize production may be attributed to 1) national policies encouraging farmers to grow more food grain crops, 2) the higher yield and thus greater cash return from maize rather than soybean, sorghum, or millet, 3) the adoption of a double-cropping system in which maize fits better than other crops, and 4) the effective use of hybrid vigor, chemical fertilizer, and high plant population.

The recovered prosperity of the rural economy during recent years has transformed China from a maize-importing nation into an exporter. During 1980-1982 we imported annually 3.95 million tons of maize from the U.S., while in 1985 we exported at least 2.5 million tons to Japan alone.

With improvement in living conditions, direct consumption of maize as a staple food has dropped to a minimum in the countryside. Contrary to the expectation that maize area might be reduced accordingly, there has been a growing demand for maize to be used as animal feed. It is therefore increasingly important that China develop maize hybrids with high lysine and high oil content to further improve human and animal nutrition.

To obtain a clearer picture of the growth rate of maize production in this country, we have compared data from two years for six leading maize producers. The data for China seem quite impressive, particularly since the country's area planted to maize in 1970 (14.6 million ha) was far below the average of 20 million ha for the period 1976-1981. The doubled output in 1980 was evidently due to the rapid expansion in area and a reasonable yield increase of 4.59% per year. By 1980 the average yield of maize in China was 3075 kg/ha, which exceeded the world average slightly, but still lagged far behind Italy (6326 kg/ha), the U.S. (5711 kg/ha), France (5326 kg/ha), Hungary (5324 kg/ha), Yugoslavia (4311 kg/ha), and Rumania (3392 kg/ha). The comparison was made, however, on the basis of unequal areas planted to maize.

We also examined production figures for China alone during different periods. Average maize yield in the country was fairly low during the early 1950s (Table 1). Between 1953 and 1983, however, area planted to maize increased 43.3%, yield 285.1%, and total output 408.9%. The average gain in yield between 1949 and 1984 was about 80.5 kg/ha, slightly higher than the figure of 63.5 kg/ha reported for the U.S. during 1937-1977.

The yield potential of maize varied with different localities, topography of the regions, weather conditions, and cultivation levels. In the Liaoning province, for instance, average yield reached 6.11 t/ha in 1984 from 1.226 million ha planted to full-season maize. That was the highest yield ever obtained among the provinces. On the other hand, during the same year in the mountainous province of Yunnan, the average yield of maize from an area of 1 million ha was reported to be 2.8 t/ha. In Guangxi the average yield from 500,000 ha was even lower at 1.9 t/ha because the crop was grown on red soils.

Maize Distribution and Cropping Systems

Maize-growing areas in China extend from 50 to 22 degrees north latitude, covering a vast territory along the eastern seacoast and reaching the highlands of Xinjiang to the west. The leading maize production area forms a broad diagonal belt from northeastern China to the southwestern provinces, passing through a large corridor in North China. Nearly 90% of the country's maize lies within the temperate zone, and approximately two-thirds of the crop are distributed in the dry, hilly and

Table 1. Maize production in China, selected years

Year	Area (million ha)	Yield (kg/ha)	Production (million t)
1953	13.13	1270.5	16.68
1963	15.37	1335.0	20.57
1973	16.57	2332.5	36.13
1983	18.82	3622.5	68.21
1984	18.53	3962.0	73.35

mountainous regions. With the exception of Xinjiang, where maize must be irrigated, most of the maize crop grown on loess soils in the semiarid mountains of North China and the northwestern provinces is rainfed. In normal years 60-65% of the annual precipitation is distributed in July and August and is sufficient for a good harvest.

Three types of maize culture can be distinguished throughout the country according to the time of planting and the cropping system.

Spring maize--This is a full-season crop planted in late April to early May. In the southwestern provinces, it may be planted earlier in March. Spring maize may be grown in a solid stand or in rows or strips in an intercropping pattern with soybeans, potatoes, peas, beans or other crops planted at the same time. This type of maize culture is very common on the northeastern plains and in the hilly or mountainous areas of other regions in China.

Summer maize--This crop fits very well into the double or multiple cropping system practiced commonly in North China. Maize is usually planted one month or less before harvest of winter wheat between the wheat rows/plots in a system that has been referred to as relay intercropping. Where the growing season is longer, summer maize may be sown after wheat harvest in a system known as sequential cropping of maize. Both cropping systems take advantage of the sunlight and land available for growing two cereal crops within a single year. But those types of maize culture are practicable only in regions with irrigation facilities, heavy fertilization, and abundant labor. Under such conditions relay intercropping might give a wheat yield of 4 t/ha and maize yield of 6 t, results which have actually been obtained in the high-yielding areas of the Shandong peninsula and central Hebei.

Autumn maize--This crop is found only in restricted areas of the Zhejiang province, where rice is the predominant crop. Maize is first sown in nursery plots and then transplanted to paddy fields in July after rice harvest.

Distinguishing characteristics of China's maize regions are listed in Table 2, and the extent of the regions is shown in the map in Figure 1. Region 1 includes three of the four provinces lying north of the 40 degrees north latitude. In two of them, Jilin and Liaoning, a greater proportion of the cultivated land (60-65%) is devoted to maize than to any other crop. Being similar to the Corn Belt of the U.S. in soil types and climatic conditions, those two provinces give high yields of maize and sorghum. Since wheat does not grow well there, maize has been the first ranked crop for many years.

Region 2 lies between 40 and 33 degrees north latitude in the northern part of China and spreads out along the Yellow, Hai, and Huai River valleys. It contains 41.5% of the nation's maize area, planted primarily to summer maize on the plains and spring maize in the surrounding mountains. As much as 60-80% of the summer maize crop by province is grown in a relay intercropping system. which is concentrated in the northern part of the region. The remaining portion of the summer crop is grown in the sequential double cropping system, whose use is made possible by the 90-95 days available for maize to reach full maturity between wheat harvest and the subsequent wheat planting.

Table 2. Characteristics of maize regions in China

	Region				
	North-eastern	North-western	North China	South-western	South-eastern
No. of provinces	4	3	5	6	6
Area in 1980 (million ha)	5.63	0.90	8.35	4.52	0.68
Percentage of total area	28.0	4.5	41.5	22.5	3.4
Climatic zone	Northern temperate	Northern temperate	Middle temperate	Southern temperate, Northern subtropical	Southern temperate
Humidity	Semihumid	Arid	Semiarid	Warm humid	Warm humid
Accum. temp. (>10°C)	2000-3600	2500-2600	3600-4700	4500-5500	4500-9000
Frost-free days	130-170	130-180	170-240	200-300	250-320
Rainfall (mm)	400-800	200-400	500-800	800-1200	1000-1700
Crop/year	1	1	2	2-3	2-3
Maize type and cropping pattern	Spring, solid and intercrop	Spring, solid	Summer, relay and sequential	Spring, intercrop	Spring, intercrop
			Spring, solid and intercrop	Summer, intercrop	Summer, intercrop
					Autumn, transplant

About 22.5% of the nation's maize is grown in region 3, known as the southwestern region, where the crop can be found on hills and high mountains ranging from 250 to 3000 m in altitude. Because of the low fertility of the red soils and many rainy or foggy days, the yield potential of maize in this region is much lower than that in North China.

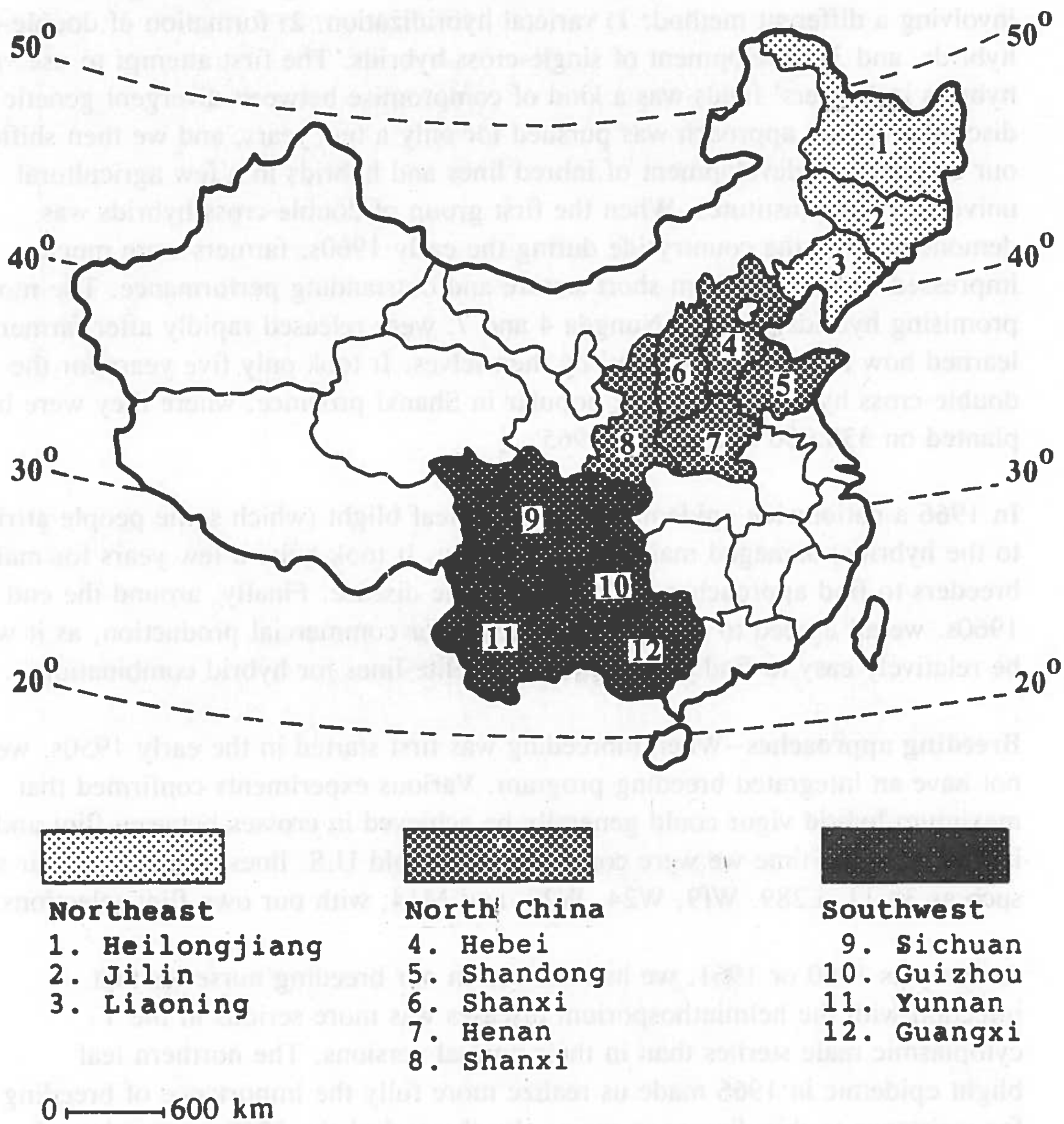

Figure 1. Leading maize regions in China.

Maize Improvement

Phases in the development of maize research--Maize breeding was begun in China as early as 1939, using conventional methods of hybrid development. The hybrids developed were never released, however, because the hybrid vigor of our flint inbred combinations was unremarkable and because the country had no seed production system.

Since 1949 work on maize improvement has gone through three stages, each involving a different method: 1) varietal hybridization, 2) formation of double-cross hybrids, and 3) development of single-cross hybrids. The first attempt to use varietal hybrids in farmers' fields was a kind of compromise between divergent genetic disciplines. That approach was pursued for only a few years, and we then shifted our emphasis to development of inbred lines and hybrids in a few agricultural universities and institutes. When the first group of double-cross hybrids was demonstrated in the countryside during the early 1960s, farmers were much impressed by their uniform short stature and outstanding performance. The most promising hybrids, such as Nungda 4 and 7, were released rapidly after farmers learned how to produce the seed by themselves. It took only five years for the double-cross hybrids to become popular in Shanxi province, where they were being planted on 330,000 hectares by 1965.

In 1966 a nationwide epidemic of northern leaf blight (which some people attributed to the hybrids) damaged maize very seriously. It took quite a few years for maize breeders to find approaches to combatting the disease. Finally, around the end of 1960s, we all agreed to adopt single crosses for commercial production, as it would be relatively easy to find just two resistant elite lines for hybrid combination.

Breeding approaches--When inbreeding was first started in the early 1950s, we did not have an integrated breeding program. Various experiments confirmed that maximum hybrid vigor could generally be achieved in crosses between flint and dent inbreds. At that time we were combining some old U.S. lines available in our stock, such as 38-11, L289, Wf9, W24, W20, and M14, with our own flint selections.

As early as 1960 or 1961, we had noticed in our breeding nurseries that infection with the helminthosporium diseases was more serious in the T-cytoplasmic male steriles than in their normal versions. The northern leaf blight epidemic in 1966 made us realize more fully the importance of breeding for resistance to this disease in maize. By the end of the 1960s, a number of high-yielding, resistant single crosses had been released in the leaf blight regions. But after a couple of years, they were found to be susceptible to head smut caused by Sphacelotheca reiliana, which was a common disease in the cool dry regions. That development made the breeding work much more complicated and burdened us with new problems. With the discovery of other diseases, such as southern leaf blight, stem and ear rot, and different viruses (notablly MDMV and rough mosaics), it became clear that we would have to search for multiple-disease resistance. This requirement was one of our principal considerations when we organized the nation's coordinated breeding program a few years ago. Since then we have succeeded in incorporating known resistance genes for one or two diseases into our breeding materials.

Some efforts have been made to incorporate the dwarf (brachytic-2) gene or upright leaf character into inbreds to achieve a more "ideal" plant type. Other breeders prefer that new hybrids have prolific ears. We have had a few prolific single crosses in our nursery, but they have not performed as well as the normal types, presumably because of the sensitivity of the former to population density, light reception, and soil fertility.

Since 1974 we have been breeding for improved protein quality in maize and are confident that high-lysine and high-oil maize will be utilized for livestock feeding and industrial purposes as well as for human consumption in China. This maize is particularly important for developing swine and poultry feeding, improving human nutrition, and increasing farmers' income.

One of the breeding approaches we have followed is population improvement, which our breeders consider to have two functions: 1) to provide better foundation materials from which elite lines can be extracted and 2) to provide improved germplasm for production in low-yielding mountainous regions.

Achievements in breeding--Hybrid maize has been grown on 12-14 million ha in China, equivalent to 65-70% of our total maize area. In the provinces with a high concentration of maize (Shandong, Liaoning, and Jilin), the proportion of total maize area planted to hybrids may be as high as 85-90%, the predominant type of hybrid being the single cross.

One of those, Zhongdan 2, has been distributed in 17 provinces. By 1983 it covered 1.73 million ha, and over the past nine years has been planted on a total of 9.3 million ha because of its wide adaptablity, high resistance to the blights and head smut, and outstanding performance.

By 1966 we had stopped using older lines both of foreign and local origin. In subsequent years testing of some well-known hybrids and public lines from different countries showed that they were not adapted to our conditions. The alternative approach to deriving inbred lines was to go through a second cycle of selection and to incorporate resistance genes into the otherwise current lines. The lines thus derived should be useful for a number of years. In fact, the commercial hybrids have been replaced three times during the last two decades. Thousands of inbred selections and hundreds of hybrid combinations have been developed and tested in the more than 10 provinces carrying out their own programs of maize breeding. Some of the prefectural institutes have been active in maize breeding and have made important contributions.

Nearly ten maize hybrids with high lysine content have been developed and undergone regional tests. In 1982 the opaque-2 hybrid Zhongdan 201 gave an average yield of 6236 kg/ha, 9.6% less than a normal maize hybrid, which gave 6900 kg/ha. The results of two separate trials conducted in 1984 and 1985 with various opaque-2 materials and normal maize hybrid check are summarized in Table 3. The hybrid Zhongdan 206 has been approved for release because of its high resistance to kernel rot, which damages the opaque-2 endosperm.

The nutritive value of high-lysine maize for swine has been confirmed through a dozen feeding trials conducted during 1981-1985. The daily weight gain of the high-lysine group averaged 40% greater than that of the group fed normal maize, and the former needed 50% less feed than the latter to gain the same amount of body weight. We concluded that high-lysine maize can be used as a substitute for at least 10% soybean meal in the formulated feeds and that it would be much cheaper than the manufactured lysine used as supplements.

Table 3. Average performance and lysine content of opaque-2 single crosses, 1984 and 1985

Entry	No. of test sites	Average yield (kg/ha)	Yield reduction (%)	Lysine per kernel (%)
Zhongdan 201	19	7186	13.07	0.488
Zhongdan 206	19	7960	3.59	0.498
Zhongdan 205	19	7321	11.40	0.468
Nungda 102	17	7415	9.65	0.425
Zhongdan 2 (CK)	19	8263	0.0	0.242

Many source materials have been offered to us by CIMMYT. Through the kindness of Dr. Norman Borlaug, for example, we were able to use Tuxpeño 1 QPM developed by Dr. Surinder Vasal for production in the Guangxi province. In the same province, the normal version of Tuxpeno 1 and cycle 15 of that population, which has short plant and is referred to as Tuxpeño Planta Baja, have spread over some 100,000 ha since their introduction in 1978.

In addition, we are using donor populations that possess modifier genes to improve the endosperm hardness of our opaque-2 lines. Incorporation of exotic germplasm into temperate materials grown in North China seems very important and is likely to produce favorable results in the near future.

Breeding for oil content in maize was commenced recently in a few institutions. In the Chinese Academy of Agricultural Sciences, we have derived a few early generation selections containing as much as 0.58% lysine per kernel and 10.2% oil based on single-plant analysis.

Problems in Maize Breeding

During a visit to China, some foreign friends claimed jokingly that they could find only three varieties in the course of their travels around the country. We took this comment as a warning that we had perhaps not paid sufficient attention to germplasm conservation. Among the more than 7000 entries of local open-pollinated varieties that we have preserved in our germplasm pool, 1656 were kept at Yunnan, 600 at Guangxi and 500 at Sichuan. A preliminary survey in Yunnan (known for its "vertical agriculture," so called because of the region's marked topographical variation) revealed that 68% of the local varieties in this province are flints, 13% semident, 6.1% dents, 11.3% waxy, and 1.5% pop types. We should have given more emphasis to evaluation and improvement of maize germplasm for the purposes of maize breeding.

In our inbred development work, the spectrum of variability has been too narrow among the current inbreds, and we have not been able to select elite lines with divergent genetic backgrounds. Often, an elite inbred line used in a superior hybrid combination has soon been made a common component in a series of hybrids bearing different numbers. As a result, there are at least 17 single crosses having an inbred pedigree of Yellow Early 4 in common. Since that line was recently reported to be infected by a new leaf blight, its wide use creates some risk of genetic vulnerability.

When extension work was begun in China, the country did not yet have a well-established system of hybrid seed production. Thus, for a time the purity and quality of inbred and hybrid seed varied a great deal with different producers, most of whom were collective farmers. Seed quality has improved somewhat since the establishment in 1978 of seed corporations at different levels. Even so, the seed sold on the market was not graded, nor was it certified. Up to the present, only a few seed factories, with varying capacities and degrees of mechanization, have been set up in the northeast. Most commericial seed is dried in the sun. In the northeastern province, however, where the temperature drops quickly in the fall, the moisture content of the seed is usually higher. There are other problems as well, involving seed quality control, seed management, and marketing.

Discussion

M.Q. Chatha: You mentioned transplanting of maize. Would you please elaborate on the raising of nurseries, time of transplanting (growth stage of the plant), and on the percentage of establishment after transplanting?

Li Jingxiong: First, the seedbed is made as fine as possible, and then fertilizer and other inputs are applied. When the seedlings are 20-30 days old, they are transplanted into shallow furrows, usually after sunset so that they will not transpire excessively. The seedlings can generally be dug up without causing too much injury to their root systems. Within a few days 90 to 100% of the seedlings are established. Irrigation is necessary.

M. Saleem: In the first hybrids released for cultivation in China, the ear tips had no grain, whereas ears of the new hybrids have full tips. Do you suppose the difference was genetically controlled or due more to environment?

How do you explain the rapid transfer of technology to farming communities within your system? What were the most important factors that helped farmers increase yields per hectare? What is the system of on-farm research in China?

Li Jingxiong: Barren tips are primarily a result of genotypic differences. This characteristic may, however, be modified by moisture or nutritional stresses at the time of ear differentiation.

Initially, many demonstrations and training exercises were conducted. Government policy was of first importance, followed by technical innovations. In the 1950s and 1960s, we carried out much on-farm research and sent staff to the countryside all year round. Currently, we do so only as needed and during the growing and harvest seasons.

G.R. Minguez: What are China's domestic requirements and uses for maize, and how does the need compare with total supply? What is the average cost of producing maize per hectare? Is there a government support price for maize? How much of the total output is white versus yellow maize?

Li Jingxiong: About 58% of the maize supply is for human consumption, 30% for feed, 7% for export, 5% for industrial uses, and less than 1% for seed and other uses. Assuming a yield of 3.75 t/ha and estimated value per kilogram of US$0.10, that yield is worth US$350. It is fairly difficult to estimate the input cost. No government subsidies are paid for maize, although the sale price might be reduced. Of the total 1984 output of 73.35 million tons, 30% was white and 70% yellow maize.

R.L. Paliwal: How do the yields of opaque hybrids compare with those of comparable normal maize hybrids? In hybrids with high lysine and high oil content, what do you expect the percentage of oil to be? What is the yield performance of such hybrids, compared with that of normal maize hybrids?

Li Jingxiong: One condition established in China for release of opaque-2 hybrids was that their yield be no less than 5% below that of the best commercial normal hybrid. Our requirements for high-lysine and high-oil maize are more than 4% lysine per kernel and 7% oil content. The best hybrid of that type in 1984 and 1985 tests was Zhongdan 206, which gave 7.96 t/ha.

Chamnan Chutkaew: Are you currently applying biotechnology in your maize breeding program, and if not, are you planning to do so in the next few years?

Li Jingxiong: Over many years of tissue culture work, we have found that some genotypes show a higher frequency of callus formation and differentiation. We are currently attempting to employ tissue culture methods in selection for disease resistance in those cases in which phytotoxins can be extracted.

Joginder Singh: How large a proportion of China's maize area is planted to high-yielding varieties? Do you mostly use single-cross hybrids? To what degree have you employed U.S. maize varieties? What is the source of the sterile cytoplasm being used in your hybrid seed production?

Li Jingxiong: Some 30-35% of the country's maize area (i.e., 6 million ha) is planted to maize varieties, of which 10-15% is planted to improved varieties. As I stated in my paper, we mostly have single crosses. At present we are using only a few current U.S. inbred lines. We have been using C type male steriles in farmers' fields since 1980.

Indonesia

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Introduction

Maize is Indonesia's second main food crop after rice. About 71.7% of the maize produced is used for human consumption, 15.5% for animal feed, 0.8% for industry, and 0.1% for export (Timmer 1984). The area planted to maize varies from year to year but averaged 2.7 million hectares between 1973 and 1983. During that time, however, the area declined by an average of 41,542 ha each year, or 1.54% of the mean area. Maize production was also variable, rising by 140,184 t/year, or 3.9% of the mean production. Yields increased consistently from 1.08 t/ha in 1973 to 1.69 t/ha in 1983 (Table 1).

The government's fourth Five Year Development Plan calls for increases in harvested maize area from 3,161,000 ha in 1984 to 3,310,000 ha in 1988, in production from 5,412,000 t to 6,656,000 t, and in yields from 1712 kg/ha to 2011 kg/ha. The need for greater production will become even more urgent in the future if the standard of living of the population, which is increasing at a rate of 2.3% yearly, is to be raised.

Table 1. Maize area, production, and yield in Indonesia, 1973–83

Year	Area (ha)	Production (t)	Yield (t/ha)
1974	2,666,868	3,010,781	1.13
1975	2,444,866	2,902,887	1.19
1976	2,095,054	2,572,139	1.23
1977	2,566,509	3,142,654	1.23
1978	3,024,611	4,029,201	1.33
1979	2,593,621	3,605,535	1.39
1980	2,734,940	3,993,771	1.46
1981	2,955,039	4,509,302	1.53
1982	2,061,299	3,234,825	1.57
1983[a]	3,017,746	5,094,645	1.69

Source: Central Bureau of Statistics, Jakarta.

[a] Preliminary figures.

Maize research should support the government's program to increase production by adopting the following goals: 1) generate appropriate technological packages adapted to various agroecosystems, 2) provide alternative solutions for nation-wide agricultural problems . and 3) collect basic information required to generate more advanced technology.

Maize Research

In the maize research program of the Central Research Institute for Food Crops. much emphasis is given to breeding and production agronomy. Research in physiology. plant protection, postharvest technology. and agroeconomy. though not yet well developed. is intended to support the breeding and agronomy work. The results of on-farm research, which was started in 1984, are reported in another section of this proceedings.

Breeding--The aim of the breeding program is to develop high-yielding. downy mildew-resistant composite varieties and hybrids that are stable under varying environmental conditions and that meet farmers' needs (Subandi 1984).

Our breeding activities include:

* Collection and introduction of new materials. an activity concentrated at the Malang Research Institute for Food Crops (MARIF) and at the Bogor Research Institute for Food Crops (BORIF).

* Development of gene pools using a half-sib system. work coordinated by BORIF. and population improvement with a full-sib system. which is coordinated by MARIF. Those methods will be modified to form a combination of a half-sib system and S_1 selection with progeny testing.

* Improvement of open-pollinated varieties for regional needs. using various approaches (mass, half-sib, and selfed progeny selection as well as various modifications or combinations of those methods). Selection pressure is intensive or mild. This work is done by individual institutes.

* Development of hybrid varieties. a task carried out mainly at Sukamandi Research Institute for Food Crops (SURIF).

* Regional yield testing, coordinated by BORIF.

* Production of breeder seed using a half-sib system; this work is coordinated by the Central Research Institute for Food Crops (CRIFC).

* Pioneering research or specific studies, coordinated by BORIF.

These activities involve cooperation with a number of other organizations within and outside Indonesia: the Directorate of Food Crops Production, Regional Agricultural Extension Services, various universities, CIMMYT, the ASEAN Cropping System Network, the Food and Agricultural Organization (FAO), and private seed companies (Cargill, Pioneer Hi-Bred International, P.T. Bright Indonesia Seed Industry, and CIBA/Funk).

Other disciplines--Work in other disciplines focuses on numerous topics, including water-use efficiency and the effect of water stress, the efficiency of N-P-K fertilizer application, liming, the use of organic matter both from mulch and stable manure, and soil cultivation (minimum tillage, cultural practices, and weed control).

Experiments on the use of insecticides are also performed, as well as a study on various aspects of downy mildew.

Socioeconomics studies concentrate on the feasibility of newly developed technologies at the experiment station and in farmers' fields, the impact of the application of new technology, and constraints to the efficient production, consumption, use, and marketing of maize.

Research Results

Superior varieties--Twenty-four open-pollinated varieties have been released by CRIFC since the breeding program began in 1923. Before independence in 1945, released varieties derived from landraces gave low yields and were susceptible to downy mildew. From 1950 to 1977, most released varieties gave higher yields (3.0-3.7 t/ha) but were late maturing and still susceptible to downy mildew. Those varieties were generally derived from introduced materials.

From 1978 to the present, released varieties have been derived from landraces as well as from introduced materials. Those varieties differ in maturity, yield reasonably well (3.3 to 5.4 t/ha), and are resistant to downy mildew. In one variety early maturity, high yield potential, and resistance to downy mildew have been combined. From 1964 to 1985, the yearly increase in yield potential of open-pollinated varieties was 2.9%. If maturity is taken into account, the figure rises to 3.1%

Metro, Harapan, Harapan Baru, and Arjuna are probably the most well known varieties, and Arjuna is the most widely grown because it is early maturing, high yielding, and resistant to downy mildew and has been well promoted.

Hybrids--In the past hybrid breeding was not done continuously and was ancillary to the main breeding work. Partly for that reason CRIFC has not yet released any hybrids. The topcrosses and single crosses developed in the 1950s yielded well but not better than the open-pollinated variety Perta. The hybrids did, however, possess a harder endosperm and more uniform grain color and size.

Topcrosses and single crosses developed in the 1960s yielded 40% more than Harapan, but conditions in the country at that time prevented the continuation of hybrid work.

Hybrids (topcrosses and single crosses) of lines developed in the 1970s yielded more than 20% higher than Arjuna, but still lower than the hybrid C-1. Some of the lines, when topcrossed to C-1 (F_2), produced 15 to 18% more grain than the hybrid C-1. Finally, in 1982 a better-defined hybrid program was set up.

Three important points related to hybrid development need clarification:

1) The CRIFC lines were derived from varieties whose yield capacity is lower than that of varieties released later (i.e., Perta, Arjuna, or Kalingga). Compared to that of the base populations, the yield capacity of the CRIFC hybrids was high.

2) Before the lines were yield tested in hybrid combinations, open-pollinated varieties (i.e., Perta, Arjuna, and Kalingga, which were derived from introductions or pool development) had been identified and released whose yield capacity was higher than that of the base populations of the lines.

3) When the CRIFC hybrids arrived at the stage of preliminary yield testing, an introduced, high-yielding hybrid, TC 63.85 from Cargill, was identified and released under the name Hibrida C-1. This was the first hybrid released and marketed in Indonesia.

Hibrida C-1 yielded, on the average, 5.8 t/ha at the experiment station and 6.0 t/ha in demonstrations in various provinces. Its release was followed by the release of a number of late-maturing hybrids from different companies and institutes (Table 2).

Pool--In the fifth generation of development, Pool 1 gave an average yield close to that of Arjuna (92%) and matured about four days earlier.

The yield of Pool 4 in the fifth generation of development was 89% of that of Hibrida C-1, and at the eighth generation was 93% of the yield given by Kalingga. The yield of Pool 4 at the eighth generation was 98% of the yield of Hibrida C-1.

Because of their wide variability and high yields, the pools should serve as good base populations for improvement.

Husk cover--When Arjuna was released in 1980 and later planted on a large scale in farmers' fields, the main complaint was that its husk cover was not good enough. In 1982, S_1 selection was begun for good husk cover and high yield. After one cycle of selection, poor husk cover was reduced significantly from 24.7 to 12.5%, while yield levels were maintained.

Table 2. Hybrid maize varieties released in Indonesia, 1983-85

Variety	Type of hybrid	Company/ Institute	Year released	Maturity (days)	Avg. yield (t/ha)	Downy mildew reaction
Hibrida C-1	Topcross	Cargill	1983	100	5.8	R
Hibrida Pioneer-1	Three-way cross	Pioneer	1985	100	5.5	R
Hibrida CPI-1	Topcross	BISI	1985	100	6.2	R
Hibrida Pioneer-2	Three-way	Pioneer	1986	100	5.9	R
Hibrida IPB-4	Single cross	Bogor Agric. Univ.	1985	100	5.4	R

Prolificacy--Selection for prolificacy was shown to be effective for increasing yield. but ear and plant height also increased. Six cycles of mass selection for prolificacy at a density of 50,000 plants per hectare in the composite variety BC 10 increased yield at a decreasing rate when evaluated at a density of 83,333 plants per hectare ($Y = 3246 + 451 X - 44 X^2$) and at a constant rate (125 kg/ha) when evaluated at a density of 27,777 plants per hectare (Subandi 1985). The increase in yield over 10 cycles of selection, in which crops were evaluated at the same density as in the selection nursery, was 92 kg/ha. Prolificacy might be one important trait to consider in population improvement when selecting or extracting families.

Earliness--Earliness is usually correlated with low yield. Selection for early silking and early maturity (browning husk) was conducted in three populations, Suwan 1 x Penjalinan, Suwan 1 x Genjah Kretek, and Bogor DMR 4 ICS2, at a plant density of 100,000 plants per hectare for five cycles at Bogor (Subandi 1985).

Selection for early silking reduced days to silk 0.8%, 2.0%, and 1.4% per cycle in the three varieties, respectively. Days to maturity were reduced 0.5%, 1.3%, and 0.5% per cycle. Selection for early maturity reduced days to maturity 0.8%, 1.5%, and 0.5% per cycle and reduced days to silking 0.9%, 1.5%, and 0.9% per cycle.

In general, selection for earliness did not significantly affect yield, barrenness, and lodging. Selection for early silking and early maturity in Suwan 1 x Penjalinan and Suwan 1 x Genjah Kretek reduced ear height 2.8 to 3.1% in the two varieties, respectively, and reduced plant height 1.4 to 1.9% per cycle. Selection for early silking in Bogor DMR 4 ICS_2 reduced ear height 2.1% per cycle.

Nitrogen and phosphorus fertilizer--Nitrogen and phosporus fertilizer experiments using the variety Harapan Baru were conducted at six locations in Java and Lampung in latosol and red-yellow podsolic soil during the dry season of 1977 and wet season of 1977-78. The average yields for 10 trials are given in Table 3 (Imtias Basa, Sachlan, Kodir, and Muchtar 1985). Similar experiments were conducted at eight locations in Java during the wet seasons of 1979-80 and 1980-81. The soil types were andosol, grumosol, and regosol.

Choosing the proper method of urea application is important for using the fertilizer efficiently. In experiments conducted at Genteng, East Java, during the dry season of 1983 and wet season of 1983-84 (Anwar Ispandi 1985), four methods of urea application (dropped in holes, covered with soil or left uncovered, and dropped on the soil surface, left uncovered or covered with soil) were used at four different rates (45, 90, 135, and 180 kg N/ha).

Covering the fertilizer produced better results during both seasons. In the dry season, highest yields were obtained by dropping the fertilizer on the soil surface and covering it with soil, while in the wet season the better method was to drop the fertilizer in holes and then cover it.

In the dry season, 135 kg N/ha, dropped on the soil surface and left uncovered (a method commonly practiced by farmers) gave about the same yield as using only 70 kg N/ha and covering the fertilizer. In the wet season the amounts were 135 and 45 kg N/ha (Figure 1).

Liming--On new land that has just been opened for transmigration, soil problems such as low pH, Al toxicity, lack of organic matter and low nutrient content are commonly encountered.

Table 3. Effects of N and P fertilizers on yield of Harapan Baru, Java and Lampung

Latosol and red-yellow podsolic soil, Java and Lampung, dry season 1977 and wet season 1977-78			Andosol, grumosol, and regosol soil, Java, wet season 1979-80 to wet season 1980-81		
N (kg/ha)	P_2O_5 (kg/ha)	Average yield, 10 trials (t/ha)	N (kg/ha)	P_2O_5 (kg/ha)	Average yield, 10 trials (t/ha)
0	0	1.28	0	0	2.40 a
45	30	2.40	0	45	3.20 b
45	60	2.27	0	90	3.35 b
90	30	2.56	68	45	3.89 c
90	60	2.55	68	90	4.77 d
135	30	2.73	135	45	4.59 d
135	60	2.78	135	90	4.90 d
180	30	3.06			
180	60	3.22			

Source: Imtias Basa, Sachlan, A. Kodir, and E. Muchtar. 1985. Pemupukan, pengapuran, dan populasi pada jagung varietas unggal. Dalam Hasil penelitian jagung, sorgum, terigu 1980-84. Risalah Rapat Teknis Puslitbangtan Bogor, 28-29 Maret 1985.

[a] All treatments included 50 kg K_2O/ha.

Experiments conducted at Taman Bogo, Lampung (pH = 5.47, Al saturation = 16.4%, exchangeable Al = 0.51 meq/100 g), during the dry season of 1975 to the wet season of 1975-76 indicated no interaction between liming and phosphate levels. Liming increased yield by about the same amount at the two application rates (3 and 4 t/ha). The first-year residual effect was the highest, followed by the second-year residual and direct effects. Spreading the lime over the soil gave the same effect on yield as liming along the maize rows, as indicated in Figure 2 (Iskander and Ismail 1983, Ismunadji and Partohardjono 1985).

Similar experiments were conducted at the same location in 1977-1980 using Harapan Baru (Iskandar and Ismail 1983). The pH was 4.78 and exchangable Al was 1.52 meq/100 g. The control yielded 1.5 t/ha; liming at the rates of 1, 2, and 3 t/ha increased yield 53%, 60%, and 100%, respectively. The yield was higher when 60 kg P_2O_5/ha was applied in addition to the lime. The first-year and second-year residual effects were obvious (Figure 3). Liming at 1 t/ha and application of 60 kg P (the yield was 3.5 t/ha) appeared to be appropriate for this soil.

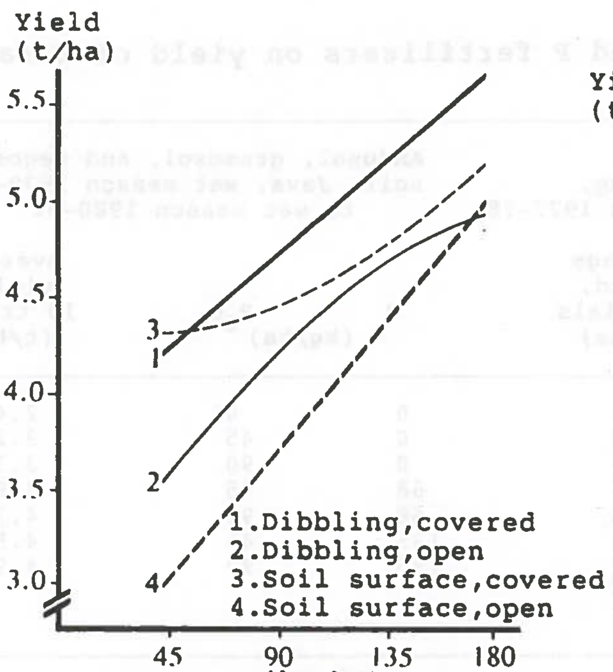

Figure 1. Effect of methods of urea application on maize yield at different rates, Genteng, WS 1983-84 (Ispandi 1985).

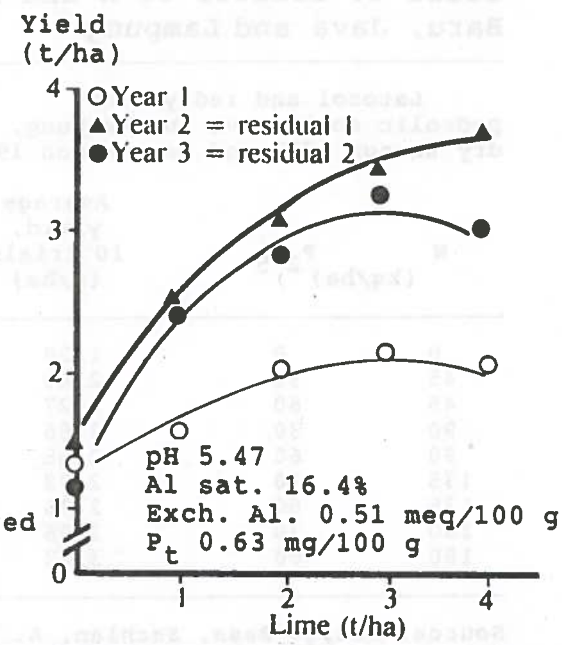

Figure 2. Effect of liming (spread) on maize yield, Tamanbogo, DS 1975-WS 1975-1976 (Iskandar and Ismail 1983; Ismunadji and Partohardjono 1985).

Experiments conducted at Sitiung 4 in soils characterized by high Al saturation indicated that liming at the rate of 1 t/ha increased yield from 0.7 to 2.1 t/ha. The rate of increase declined at higher rates of lime (Figure 4). Yield increased linearly when 0 to 135 kg P_2O_5 was applied, as indicated in Figure 5 (Ismunadji and Partohardjono 1985; Syaiful, Tastra, and Karama 1984).

Mulching--In Indonesia the soil usually lacks organic matter, weeds are a serious problem, and low soil moisture often results in poor yields. Experiments conducted in Rambatan, West Sumatra (upland), during the dry season of 1983 and in East Aceh (rainfed land) during the dry season of 1982 indicated that application of organic matter as mulch at 6 t/ha increased maize yield 1.6 t/ha or more (Iswandi et al. 1985).

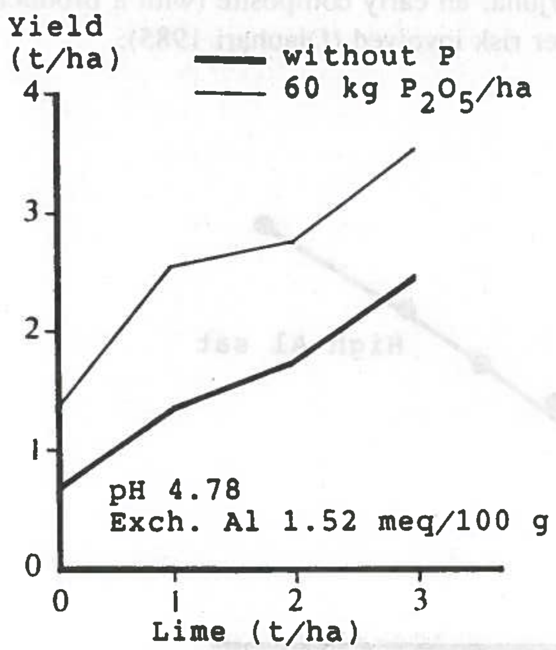

Figure 3. Effect of lime and phospate on yield of Harapan Baru, Tamanbogo 1977-80 (Basa et al. 1985; Iskandar et al. 1978).

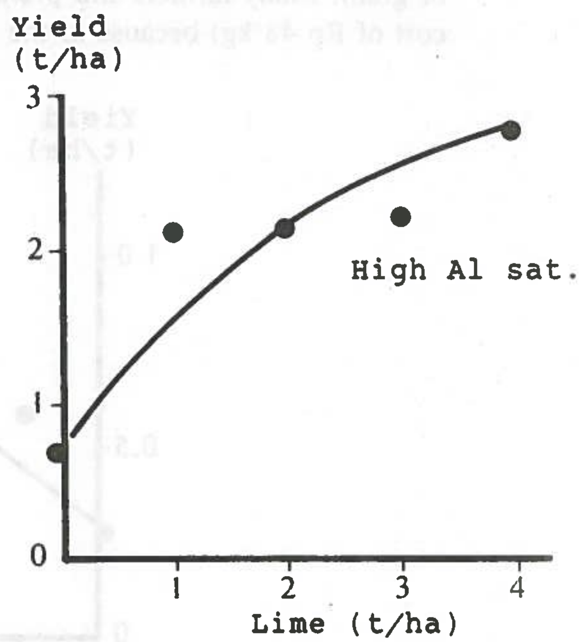

Figure 4. Effect of liming on maize yield, first year, Sitiung 4, WS 1982-83 (Ismanadji and Partohardjono 1985; Syaiful et al. 1984).

Planting methods--The traditional way of planting maize (dibbling seed by hand) is laborious. A maize planter has been developed that makes holes at the desired spacing, drops seeds in the holes, and covers seeds with soil (Mansur Lande and Momuat 1985). This implement could reduce the labor requirement of planting from 15 to 3.5 h/ha.

Agroeconomy--At the national level, maize farming gives the lowest profit when compared with other secondary (palawija) crops. By 1980 production costs had decreased by only Rp 2/kg from the 1976 costs. One reason for the small decrease was that greater use of fertilizer was not accompanied by the use of high-quality seed of superior varieties.

The costs of production when the hybrid C-1 is used varies from Rp 37 to Rp 47/kg of grain. Many farmers still prefer Arjuna, an early composite (with a production cost of Rp 48/kg) because of the lower risk involved (Djauhari 1985).

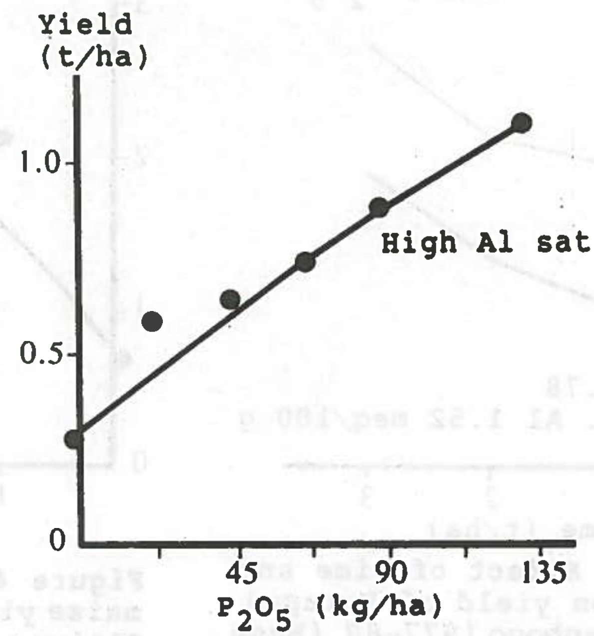

Figure 5. Effect of phospate (TSP) on maize yield, Sitiung 4, (Ismunadji and Partohardjono 1985; Syaiful et al. 1984).

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Discussion

M.Q. Chatha: You recommend the same levels of P_2O_5 and K_2O for open-pollinated varieties and hybrids. whereas a higher nitrogen level is recommended for hybrids than for open-pollinated materials. Why is this so?

Subandi: These are the combinations that we thought to be most profitable for each of the types of germplasm in general.

Kiramat Khan: With special reference to fertilizer recommendations. which morphophysiological plant characters differentiate open-pollinated varieties from hybrids under Indonesia's climatic conditions?

Subandi: Different recommendation rates are mainly associated with yield.

Kiramat Khan: Was the variety Arjuna's failure in large-scale production caused by lack of information about husk cover from on-farm testing. or was the variety not subjected to on-farm testing before its release in 1980?

Subandi: Arjuna is now produced on a large scale, and the problem of poor husk cover is gradually being overcome through selection during basic seed production. Farmers are also advised to deal with the problem by eating the grain from poorly covered ears first. and storing ears with better husk cover.

Joginder Singh: Did selection for prolificacy affect root or stalk lodging?

Subandi: We did not see any significant effect in the study we conducted, probably because of the high error term for that trait.

Joginder Singh: Did you measure the additive response to nitrogen between varieties with stay green and alternate varieties?

Subandi: No, we did not conduct trials on the response of nitrogen to the stay green character.

Joginder Singh: What regression value (b) would you suggest for varietal recommendation?

Subandi: We would like to see b=1, as this would indicate more stability, especially under our conditions, where small environmental niches each require a distinct set of recommendations.

S.C. Dalmacio: Which species of downy mildew are found in Indonesia? And aside from downy mildew, which other maize diseases require attention?

Subandi: In Indonesia, the common downy mildew species is *Peronosclerospora maydis*. Other disease problems include the rusts (*Puccinia* spp.), leaf blight (*Helminthosporium maydis* is a problem at high elevations, and *H. turcicum* at both high and lower elevations), and ear rots, which are a problem at high elevations.

Joginder Singh, All-India Coordinated Maize Improvement Project, Indian Agricultural Research Institute

Among cereal crops in India, maize ranks fifth after rice, wheat, sorghum, and pearl millet in total area, fourth in production, and third in productivity. From 1974-75 to 1984-85, total area planted to maize stabilized around six million hectares and total production increased from 5.56 to 8.36 million tons. Productivity rose from 948 to 1441 kg/ha in the same period. The Sixth Plan Mid-term Appraisal of the Planning Commission recorded a growth rate (from 1949/50-1951/52 to 1978/79-1980/81) of 4.1% for maize, compared to 6.0% for wheat, whereas rice (2.9%), sorghum (2.3%), pearl millet (2.3%), pulses (0.8%), and oilseeds (1.8%) showed lower growth rates. Data relating to area, production, and yield of maize during the past five years (Table 1) suggest a steady increase in production and productivity that was not linked to increase in area.

Unlike the areas where wheat and rice are grown, over 80% of the maize area in India is rainfed land. A large portion of the maize area is irrigated in the states of Punjab (68.1%), Tamil Nadu (84.2%), and Karnataka (82.2%), yet the impact on overall maize production is rather limited since the maize area of these states accounts for less than 10% of India's total maize area. The states of Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, Punjab, Jammu and Kashmir, Gujarat, Himachal Pradesh, and Andhra Pradesh, which account for 90% of the maize area and 85% of total production, have a very low portion of their maize area under irrigation. By and large, most of the land planted to maize depends on natural precipitation. Total rainfall and rainfall distribution are not precisely predictable. Maize productivity is affected by moisture stress, especially during flowering and grain filling, and also by excess moisture when the soil is waterlogged.

Table 1. Area, production, and yield of maize in India, VI Plan period

Year	Area (000 ha)	Production (000 t)	Yield (kg/ha)
1980	5982.8	6804.3	1159
1981	5934.7	6897.1	1162
1982	5720.3	6548.5	1145
1983	5858.6	7922.2	1352
1984	5799.3	8355.9	1441

Maize in India is grown in most states across a wide range of agroclimatic regions. Requirements for maize of different maturity classes and grain type vary substantially throughout the country. In view of the high dependence on natural precipitation, farmers in the Indo-Gangetic plains prefer to grow early to very early maturing maize varieties, whose growing period is synchronous with average rainfall distribution.

Over 85% of the grain produced is used for human consumption, for which flint to semiflint types are preferred. Thus most maize grown under rainfed conditions has a flint to semiflint grain type and matures early or very early, although in areas with irrigation or assured rainfall, full-season and medium-maturity varieties are also grown. Considerable attention has been given to developing materials that can be adopted rapidly by farmers.

Research Organization

The All-India Coordinated Maize Improvement Project (AICMIP) is the sole organization fully devoted to all aspects of maize improvement in India. This project was formally launched by the Indian Council of Agricultural Research (ICAR) in 1957, and the Rockefeller Foundation cooperated actively. Currently AICMIP has 22 research stations and three national nursery stations located in the major maize-growing regions of the country. For an in-depth study of the nature of the problems encountered by maize farmers, and to generate more efficient crop production technologies, AICMIP divided the major maize-growing regions of the country into five broad agroecological zones:

Zone I (Himalayan Zone)--This zone covers temperate maize-growing regions above an elevation of 600 m that receive moderate to heavy rainfall. The duration of the crop in this zone is longer than in other zones, and medium to full-season varieties are usually grown. Generally only one crop of maize is grown each year because snow and frost are common in the winter season. States in this zone are Jammu and Kashmir, Himachal Pradesh, Sikkim, and the hill regions of Uttar Pradesh, West Bengal, and Northeastern India.

Maize cultivation has more recently been extended into regions from 2500 to 3000 m above sea level. Regions above 2000 m require varieties that mature extra early and dry quickly at low temperatures.

Zone II (Northwest Plains Zone)--This zone is characterized by a hot, arid climate and elevations below 600 m. Maize is frequently subjected to soil moisture stress, especially during the flowering and grain-filling periods. Farmers usually grow varieties of medium to early maturity. The states included in this zone are Delhi, Rajasthan, Punjab, Haryana, and western Uttar Pradesh.

The winter season is cool; there is no snow, but ground frost is recorded at a few locations. Monsoon, winter, and spring crops can be grown successfully in most areas of this zone.

Zone III (Northeast Plains Region)--Maize-growing areas in this region have hot, humid weather. Fields are sometimes waterlogged. Weather conditions are favorable for growing three crops of maize per year (monsoon, winter, and spring crops). Ground frost is rarely recorded in this zone, which covers areas of Uttar Pradesh and Bihar States. Those two states account for one-fourth of the area planted to maize nationwide.

Zone IV (peninsular India)--This zone is characterized by a tropical to subtropical climate. The elevations at which maize is grown vary; conditions in the coastal areas are more favorable for growing maize, although sometimes foliar diseases are a problem there. Maize can be grown throughout the year if soil moisture is sufficient. States included in the zone are Gujarat, Madhya Pradesh, Maharashtra, Orissa, Andhra Pradesh, Karnataka (which has the highest level of productivity), and Tamil Nadu.

Zone V (flood-prone areas)--The flood-prone (diara) areas of Uttar Pradesh and Bihar require extra-early maturing maize. Winter, spring, and summer crops can be grown successfully in most parts of this zone. Hybrids of full-season maturity grown in the winter and summer seasons yield well.

Each zone has one main research station and one or more research centers. Locations of research stations and disciplinary composition of staff are given in Table 2.

Maturity Grouping

To realize optimum yield, it is of utmost importance to choose the proper variety, especially in regions that are entirely dependent on natural precipitation, since the duration of maturity should be synchronous with long-term rainfall patterns. The AICMIP recognizes five broad maturity groups:

Maturity Group A (full-season maturity)--Varieties of this group take 105-110 days or more to mature and are suitable for areas with assured rainfall (if seed is sown at the appropriate time) or irrigation. This group is represented by hybrids like Ganga 5, Ganga 9, and Deccan 103.

Maturity Group B (medium-maturing varieties)--Varieties in this group require 95-100 days to mature and are good for areas with assured rainfall. This group is represented by composite Tarun and Agetic 76, among other materials.

Table 2. Organization of the All-India Coordinated Maize Improvement Project

Zone		Main center	Research stations
I	Himalayan region	Srinagar (Jammu and Kashmir) BAE[a]	Almora (Uttar Pradesh) BA Bajaura (Himachal Pradesh) BAP Solan (Himachal Pradesh) BA Kalimpong (W. Bengal) BAP Gyalzing (Sikkim) B Auli (Uttar Pradesh) BA Jorhat (Assam) B
II	North-western plains	Delhi BAPES	Ludhiana (Punjab) BAE Udaipur (Rajasthan) BAPE Kanpur (Uttar Pradesh) BA
III	North-eastern plains	Pantnagar (Uttar Pradesh) BAPES	Dholi (Bihar) BAPE
IV	Peninsular India	Hyderabad	Mandsaur (Madhya Pradesh) BA Dharwad (Karnataka) BA Godhra (Gujarat) BA Kolhapur (Maharashtra) BAE
V	Diara area	Varanasi (Uttar Pradesh) BA	Sabour (Bihar Pradesh) BA Bahraich (Uttar Pradesh) BA
	Coordinating Unit	New Delhi	Coordinating Unit (New Delhi) Biochemical Laboratory (New Delhi) Winter Nursery Station (Hyderabad) Nucleus Seed Production Centre (Karnal)
	National nurseries		Mandya (foliar diseases) BP Dhaulakuan (stalk rots) BP Banswara (Rainfed) BA

[a] A = agronomy, B = breeding, E = entomology, P = pathology, and S = soil science

Maturity Group C (early maturing varieties)--Varieties in this group (e.g., composite Hunius) take 80-90 days to mature and are suitable for either monocropping or intercropping under rainfed conditions.

Maturity Group D (very early maturing varieties)--These varieties need 75-80 days to mature and are represented by the composites Diara, Diara 3, and D 765. They are especially suited for cultivation in flood-prone areas as a summer season crop and as an intercrop under rainfed conditions.

Maturity Group E (extra-early maturing varieties)--This group, represented by composite Auli, is especially suited for cultivation under rainfed conditions at elevations above 2500 m, where the growing season is very short and the temperature is relatively low.

Breeding Program

Maize hybrids--To meet the needs of farmers growing maize under differing agroclimatic and farming conditions, various AICMIP research stations have devoted considerable attention to the synthesis and further improvement of high-yielding hybrids and composite varieties of different maturity groups.

In the early 1950s, a number of high-yielding hybrid introductions from the USA, Australia, and a few other countries were evaluated in major maize-growing regions of India. Hybrids such as Texas 26, NC 27, and Dixie 18 gave high yields but could not be put to commercial use for several reasons. The parental inbred lines proved susceptible to downy mildew and stem borers; they also lacked vigor and had poor pollen shedding capacity. Because of their dent grain type, they were not readily accepted by farmers and consumers, who preferred flint varieties.

From indigenous materials, a number of double-cross and three-way hybrids were developed. By the mid-1950s it was evident that the local varieties did not have enough genetic diversity to provide high-yielding hybrids. Maize hybrids involving Indian x exotic (or flint x dent) materials generally yielded better than Indian x Indian (flint x flint) materials and had acceptable semiflint grain type. Through the systematic mobilization of elite Indian materials and germplasm introduced from Central and South America and the USA with the help of the Rockefeller Foundation, four high-yielding double-cross hybrids (with a yield superiority of 30% over the best locally available material) were identified in 1961. The parental inbred lines of these hybrids were vigorous and possessed a good level of resistance to diseases and insect pests of major economic importance.

A number of additional hybrids were developed and recommended for commercial cultivation in various parts of the country. To date, 18 high-yielding hybrids with wide adaptability have been identified from a very large number developed and evaluated at AICMIP research centers. These include: Ganga 1, Ganga 101, Ranjit, Deccan, Ganga Safed 2, Ganga 3, Ganga 4, Ganga 5, Ganga 7, Ganga 9, Him 123, Hi-starch, Him 128, VL 54, VL 42, Deccan 101, Deccan 103, and Sagam. These hybrids are of medium to full-season maturity, have yellow/white semiflint grain, and are double-cross or double-topcross hybrids (single cross x variety). Among these two types of hybrids, the double-topcross hybrids have higher seed sales because of their wider adaptability and higher seed yield.

By the mid-1960s it was concluded that it was not possible to develop more productive hybrids by reshuffling the locally available inbred lines used in earlier cycles of hybrid development. Instead, it was better to improve the base population to develop more productive and better combining inbred lines. Two cycles of reciprocal recurrent selection in three pairs of populations provided a number of inbred lines, which formed the pedigree of a series of new hybrids that, not only gave higher yields, but had better levels of resistance to foliar diseases and stalk rots. To meet future needs more efficiently, two pairs of broad-based heterotic pools have been developed. Interpopulation improvement programs have been planned to provide better inbred lines for formation of single-cross hybrids.

High-yielding composite varieties for commerical use--In the early 1960s, work began at the main research station of AICMIP to develop broad-based composites from which more productive and better combining inbred lines could be extracted for the synthesis of more productive hybrids. In the synthesis of these composites, elite genotypes introduced from the US Corn Belt, Central and South America, and India were pooled. These populations were random mated for a few cycles before initiating inbreeding. Their performance through various cycles of random mating was impressive and encouraged breeders to evaluate them in detail. Based on extensive tests, a number of composite varieties were found to yield 90-95% of the grain yield of the best hybrid under commercial cultivation. These composites also showed wide adaptability and good response to better crop management.

In 1967, six composite varieties (Vijay, Kisan, Amber, Sona, Jawahar, and Vikram) were recommended for commerical cultivation. Research was continued to develop additional composites with higher levels of productivity. An accelerated research program led to the identification of more than three dozen composites (Table 3) that have been found to do well either in specific states or across the country. This list includes composites of various maturity groups. Besides being convenient for seed production, composite varieties can be further improved through various intrapopulation selection schemes.

Intrapopulation improvement--A systematic intrapopulation improvement program was initiated in the mid-1970s. Broadly speaking, three selection schemes were used to improve a number of composite varieties: unit selection, full-sib selection, and half-sib selection.

Unit selection involves the evaluation of 150 to 200 units of size six (Singh 1983) developed either in a single population (simple unit selection), among two populations (reciprocal unit selection), or more than two populations (multiple convergent unit selection). Units are evaluated for a set of desired traits at 3-4 representative environmental sites. Two contrasting levels of selection intensity are used. A relatively mild level of selection intensity of 25-30% helps retain an adequate level of genetic diversity among the units of the next cycle of evaluation, while further individual evaluation of a few more promising units, based on several characters, helps realize high gains in each cycle of selection.

Table 3. Composite varieties recommended for commercial use

Maturity group	Type	Variety
A Full season	Yellow	Amber, Jawahr, Kisan, Sona, Vijay, Vikram, Chandan-1, A-de-Cuba, C1, C2, Navin, Shweta, Navjyot, C14, Partap, Trikuta, Nishat, Manjari, Chandan 3, CO 1
	White	Moti, NLD
	Opaque-2	Shakti, Rattan, Protina
	Forage	African Tall
	Popcorn	Amber Pop, VL Amber
B Medium		Tarun, MS1, Ageti 76, Super I, Kanchan
C Early		Hunius, VL 16
D Very early		Diara, Kanchan, Rajendra I, Diara-3, D 765

Studies in several populations have revealed that 15-20% of the units registered more than 10% higher yields, and the best unit recorded 15-20% higher yield than the base population. Gains recorded in PK Hunius over three cycles of selection were encouraging (Table 4).

During the past three years, four units of different maturity groups, MCU 508 (D-maturity), MCU 314 (B-maturity), and MCU 216 and MCU 204 (A-maturity) were identified from coordinated trials in preference to other elite materials developed through other selection schemes. Besides yielding well, these units were superior for a set of other agronomic traits.

Recently, a study was undertaken to determine the likely level of gain that could be realized from selection within a unit of six. Three cycles of selection within MCU 314 have given good gains. Intraunit selection would not only help realize additional gains but would impart greater uniformity in the cultivar ultimately recommended for commercial cultivation.

Singh et al. (1984) suggest the use of unit selection in a half-sib and full-sib family selection program involving the 8-10 elite progenies selected. Evaluating a large number of units among selected progenies, instead of developing only one improved variety, provides a better opportunity to identify superior improved cultivars of the population.

Table 4. Performance of units of six in PK x Hunius

	1981 Cycle 1	1982 Cycle 2	1983 Cycle 3
Total number of units tested	87	135	81
Number of units yielding 10% more than the best check	10	23	11
Percentage of units yielding 10% more than best check	11.5	17.0	13.6
Percentage of units yielding 10% more than base population	45.8	7.4	27.3
Range in yield (kg/ha)	2051-4406	2004-4561	1432-2760

Singh (1983) suggests using units to develop nonconventional hybrids. These "ultra-hybrids" have three advantages:

* High yield of seed parent
* Possibility of making simple hybrids with a limited level of variability
* Possibility of improving performance of unit hybrid through interunit selection as well as through base improvement

Initial studies helped identify a few unit hybrids that recorded 10-15% higher yields than the best hybrid available in the program.

Full-sib family selection has been practiced in 10 populations of various maturity groups. Full-sib progenies were evaluated at four to six locations and two different levels of selection intensity. An intensity of 25-30% was used in regenerating progenies for the next cycle of evaluation, and a 4% intensity was used to develop location-specific and across-location improved varieties.

The data available suggest that gains realized through full-sib family selection varied substantially in different populations, although on average the gains (based on Diara composite, in which 10 cycles of selection have been completed) were about 3% per selection cycle. In initial cycles of selection (up to C5), the across-location improved varieties were comparable to or better than the location-specific improved varieties. In later cycles, however, a few of the location-specific improved varieties performed better. Gains were higher in cycles when advanced-generation seed was used in the synthesis of improved varieties.

Composite Diara C5 was comparable with C0 with regard to maturity and genetic variability (Chaudhury and Singh 1983). That study also revealed the presence of a substantial proportion of additive genetic variation in C5 for realizing further gains through selection. In addition, it was found that the additive genetic variance was reduced while the dominance variance increased. Although no increase in the duration of the flowering period was recorded, a slight increase in plant height was observed. The observed gain of 3% was smaller than had been predicted.

A recent study (Singh et al. 1986) in Diara C7 was undertaken to determine if full-sib family selection at different sites was effective in retaining divergent alleles and to identify the best sites for selection of more favorable alleles. Among the sites sampled, it was observed that the stress environment of Bahraich helped in the selection of more divergent alleles (Table 5).

The half-sib selection scheme was initiated in five broad-based pools, namely AB (yellow), AB (white), BC (yellow), CD (yellow), and CD (white). About 400 half-sib progenies were evaluated in the monsoon season at three to four locations. At each location progenies were grown in a half-sib block with two replications. Seed for the male rows was provided by a balanced composite of selected progenies. From each location 60-80 progenies were retained and grown in a recombination nursery, which yielded progenies for the next cycle of selection. Four to five cycles of selection have been completed in each of the five pools. In each cycle of selection, elite progenies were used to synthesize improved varieties. Both unit

Table 5. Grain yield among all possible crosses of six improved varieties of Diara (cycle 7)

Diara varieties	(IFS 7) Godhra	Diara (ZFS 7) Across	Diara (SFS 7) Sabour	Diara (UFS 7) Bahraich	Diara (MFS 7) Dholi	Diara (VFS 7) Varanasi	Diara Array mean[a]
IFS 7							
1984	2466	3267	3345	3227	2995	3382	3243
1983	2918	1876	2324	2761	2642	2134	2347
Mean	2692	2572	2834	2994	2818	2758	2795
ZFS 7							
1984		2135	2940	3082	2892	2737	2984
1983		2178	2227	2482	2006	2290	2176
Mean		2156	2584	2783	2449	2513	2580
SFS 7							
1984			3058	3874	3233	1728	3024
1983			2356	2619	2234	2100	2301
Mean			2707	3246	2733	1914	2662
UFS 7							
1984				2889	2853	3068	3221
1983				2553	2599	2580	2608
Mean				2721	2726	2824	2915
MFS 7							
1984					2923	2402	2875
1983					2305	2400	2376
Mean					2614	2401	2625
VFS 7							
1984						2585	2663
1983						2605	2308
Mean						2595	2482

a Excluding the parent.

	CD at 5%	CV %
1984	473	11.4
1983	454	11.4
Combined	425	11.5

selection and selective matings through chain crosses were used. Improved varieties developed through both approaches registered marked superiority over the base population, although the unit selection provided additional opportunities to select for desirable characters in addition to yield.

Protein quality improvement--In the early 1970s, three opaque-2 composites (Shakti, Rattan, and Protina) developed from elite composite varieties were identified for commercial cultivation in various maize-growing regions of the country. The endosperm of the kernels of these varieties had 100-160% more lysine and tryptophan than did that of other varieties. In a supplementary feeding study with children from 18 to 30 months of age, it was noted over a period of six months that gains in body weight and height of children fed opaque-2 maize were comparable to or better than weight gains in the group fed skim milk (Singh et al. 1980).

The lack of wide acceptability of opaque-2 varieties was attributed to their soft, chalky endosperm and the resulting storage problems. Attention has therefore been given to improving the vitreosity of opaque-2 maize kernels. Ten cycles of selection in seminormal semiopaque (SO/SN) composite developed from elite opaque-2 materials revealed that:

* The frequency of chalky kernels rapidly decreased.

* Though the frequency of modified kernels increased, it was rather hard to surpass the 85-90% frequency of seminormal kernel types.

* The influence of the environment was rather dominant in the expression of vitreous endosperm; a higher frequency of vitreous kernels was found in the cool winter season than in the monsoon season.

* Marked reciprocal differences in kernel vitreosity were observed, necessitating the use of reciprocal full-sib family selection, a scheme which gave high gains.

* Chemical analysis of various grades of vitreous kernel types revealed a positive association between improvement in kernel vitreousness and total protein content. Levels of tryptophan and lysine were observed to decrease with increased kernel vitreousness.

An initial study with the SO/SN composite revealed that the level of nitrogen applied to the crop and the stage of harvest have a marked influence on the frequency of various grades of vitreous kernels. Evaluation of full-sib progenies of composite Diara for tryptophan and protein content revealed the possibility of improving protein quality in the absence of major endosperm-modifying genes. This approach would help obviate the need to select for vitreous kernels, which is of prime importance in the background of opaque-2.

Improving forage quality--The simple recessive gene bm3, which is known to reduce the lignin content of the stalk, was introduced into the background of a number of elite maize varieties. A 1-2% reduction in lignin content and a 1-2% increase in protein content were observed. In general, the bm3 versions tended to be less vigorous and had lower dry matter production, although the level of reduction varied according to the genetic background. The performance of bm3 was observed to be most desirable in the full-season tropical composite, Africa Tall.

Cultivation of Maize in the Winter Season

In most parts of India, maize has traditionally been grown in the monsoon season. More productive hybrids evaluated during the winter season over the past decade at various research centers of AICMIP have given very encouraging yields. Yields of 4-6 t/ha were frequently reported from the experiment stations and farmers' fields, though yields of 6-8 t/ha were not infrequent. High yields were generally realized only through the use of newly developed high-yielding hybrids and composite varieties, whereas the local varieties traditionally grown in the rainy season did not perform well in the winter season. Throughout India, maize has been found to be a more profitable winter crop than traditional winter season crops.

Suitable agronomic management techniques have been devised to avoid problems with frost, especially in the northern regions. High grain yields realized in the winter season (compared to those in the rainy season) have been attributed to the longer growing season, more favorable temperature regimes, and opportunities for better management of water resources and weed control.

Performance of experimental varieties/hybrids in the monsoon and winter seasons has shown a genotype x season interaction. Thus it is important to choose an appropriate hybrid/composite variety to realize high yields in a particular crop season.

Varietal Testing and Performance

A well-defined code for evaluating and selecting materials has been in use for many years. All new materials developed or improved at the research centers are systematically evaluated within a three-tiered system of coordinated trials. The materials are grouped into five broad maturity groups as described earlier and evaluated in three stages, each consisting of yield trials that are separately conducted for each maturity group (the stages are distinguished primarily by the plot size of the evaluations). All entries that qualify for stage I have been tested in zonal trials or in at least two environments and have yielded 10% better than the best check entry of the specific maturity group. The test variety should have a duration of flowering similar to that of the check entry (within a limit of 1.5 days) with which the yield comparison is made.

Elite varieties are likewise promoted from stage I to II to III. Varieties must be evaluated in linear order; there is no provision for lateral entry. Promotion is made for one or more zones or over all zones. In addition to yield and maturity, reaction to diseases and insect pests and various agronomic traits is taken into consideration.

Following the successful performance of varieties in stage III, data for all past years are compiled and the overall performance of the materials is reviewed. Promising varieties are evaluated in minikit trials in farmers' fields. It is essential to have information from those trials before a variety can be recommended for release for commercial cultivation.

In addition to being evaluated for yield, maturity, and agronomic traits, all test entries in stages II and III are studied for their reaction to important diseases and insect pests under artificial inoculation. Data from trials conducted under natural as well as artificial disease or insect pressure are used in selecting varieties. Agronomists evaluate all elite varieties in stage III for their response to different levels of nitrogen application and different sowing dates.

Data from all trials conducted at research stations by scientists from different disciplines are reported in the Annual Progress Report, and stability parameters are computed for all breeding trials. To illustrate that system, data for coordinated trial 69 (stage III, maturity group A) and their stability parameters for the various zones are given in Tables 6, 6A, and 7.

AICMIP annually conducts two separate coordinated testing programs, one for the winter season and another for the monsoon season. To review the results of these programs, two separate Annual Progress Reports are prepared and discussed at the respective annual workshop meetings.

Table 6. Performance of maturity group A composites at 16 locations, stage III, trial 69, <u>kharif</u> season, 1984.

Entry no. & pedigree	Yield (t/ha) at 15% moisture at various locations[a]															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 J-115	5.6	7.1	2.7	4.4	7.5	5.9	4.4	4.4	4.0	3.6	3.9	2.1	3.7	4.2	5.8	3.4
Checks:																
2 Vijay	5.9	7.5	3.2	3.6	5.9	5.8	4.0	4.0	4.7	3.3	3.0	1.8	4.0	3.5	4.9	2.9
3 Deccan 103	4.9	7.3	3.0	3.4	6.7	6.1	3.4	4.1	4.5	2.6	4.2	2.2	4.8	5.5	5.5	3.6
4 Ganga-5	6.2	5.1	2.5	2.7	6.0	5.2	3.8	3.7	5.3	3.1	2.4	1.8	3.2	3.2	5.4	3.1
5 Local	6.2	6.7	2.3	--	--	3.2	3.8	4.0	3.5	3.5	1.4	1.5	4.8	4.4	4.7	3.8
CD (5%)	0.8	1.1	0.3	8.2	0.8	1.3	0.4	0.6	0.6	0.3	0.4	0.7	0.6	0.8	1.1	0.6
C.V. (%)	8.6	10.6	8.9	13.3	9.2	13.6	6.0	9.3	11.2	6.9	13.0	11.5	8.6	25.5	14.0	11.5

[a]The trial locations and materials used as checks at these locations (indicated in parentheses) were as follows: 1 Poonah (local), 2 Solan (local), 3 Delhi (Basi), 4 Ludhiana (local), 5 Gurdaspur (local), 6 Karnal (local), 7 Kanpur (K 741), 8 Banswara (Imp. local), 9 Pantnagar (KT 41), 10 Dholi (Suwan comp.), 11 Dharwar (local), 12 Godhra (Farm Sumeri), 13 Kolhapur (Manjri, ZFS6), 14 Kolhapur, SP (Manjri, ZFS6), 15 Coimbatore (UMC-5), and 16 Varanasi (local).

Table 6A. Performance of maturity group A composites at 16 locations, stage III, trial 69, <u>kharif</u> season, 1984

Entry no. & pedigree	Ear height (cm) at various locations[a]										
	1	2	3	4	5	6	7	8	9	10	11
1 J-115	86	98	129	110	91	114	79	76	73	56	103
Checks:											
2 Vijay	100	116	140	117	84	118	82	101	80	81	115
3 Deccan 103	90	93	120	115	89	102	75	84	72	57	109
4 Ganga-5	100	100	138	116	99	115	74	91	82	57	120
5 Local	90	--	--	103	72	115	87	80	68	60	104

[a]The trial locations were as follows: 1 Delhi, 2 Ludhiana, 3 Gurdaspur, 4 Karnal, 5 Kanpur, 6 Banswara, 7 Dholi, 8 Godhra, 9 Kolhapur, 10 Kolhapur (SP), and 11 Varnasi.

Table 7. Stability estimates for material in trial 69, kharif/rabi (winter) seasons, 1984

Zone	Variety	Mean yield (kg/ha)	Regression coefficient
I	1	6334	1.50
	2	6691	1.74
	3	6109	2.43
	4	5647	-1.23
	5	6458	0.57
CD (5%)		669	
SE		217	
General mean		6247	
II	1	4885	1.27
	2	4422	0.89
	3	4451	1.18
	4	3896	1.06
	5	3683	0.59
CD (5%)		354	
SE		115	
General mean		4285	
III	1	3788	0.32
	2	4004	1.18
	3	3558	1.59
	4	4236	1.92
	5	3495	-0.01
CD (5%)		421	
SE		137	
General mean		3816	
IV	1	4164	1.01
	2	3437	0.85
	3	4480	0.95
	4	3211	0.98
	5	3379	1.21
CD (5%)		451	
SE		146	
General mean		3734	
All	1	4614	1.15
	2	4250	1.05
	3	4505	0.99
	4	3924	0.95
	5	3920	0.95
CD (5%)		1183	
SE		384	

During the past ten years, the area under the High-Yielding Variety Program has been increasing (Table 8). Coverage varied considerably in different states.

Selection of Varieties for Intercropping

Earlier agronomic studies indicated that short-duration varieties of oilseed and pulse crops can be intercropped very successfully with maize. Yields of intercropped maize were not reduced, and the intercrop provided a bonus. Based on that information, studies were initiated to identify suitable genotypes for three intercropping systems: maize-groundnut, maize-pigeonpea, and maize-moong/urd.

Marked variability in the performance of maize varieties, in pure stands and intercropped, was recorded for groundnut and moong (green gram) and urd (black gram). Variability for pigeonpea was less evident (Table 9). Additional work on maize intercropping will be undertaken in the near future.

Agronomic Investigations

Use of intermaturity varietal blends--It is rather difficult to make the best use of natural precipitation when a variety with fixed maturity is grown. For a specific region, short-duration varieties would be the conservative choice, whereas the optimistic approach would be to choose somewhat later maturing types. Though the conservative approach does not involve much risk, at the same time it is not the best choice if rainfall is above normal.

Table 8. Area under the High-Yielding Varieties Program (HYVP), 1975-84

Year	Total area under maize (million ha)	Area under under HYVP (million ha)	Percent area under HYVP
1975	6.030	1.13	19
1976	6.000	1.06	18
1977	5.682	1.24	22
1978	5.760	1.35	23
1979	5.752	1.35	23
1980	6.005	1.58	26
1981	5.935	1.60	27
1982	5.720	1.72	30
1983	5.857	1.81	31
1984 (target)	5.798	2.00	34

In the past three cropping seasons, equiproportional blends of varieties of maturity groups A, B, C, and D were evaluated in all possible combinations of two, three, and four varieties under rainfed conditions. Generally the AB and BC blends (BCD in a few cases) performed better than the pure stands. Our earlier studies of intramaturity blends showed a limited advantage in stress environments.

The use of intermaturity blends helps make optimum use of natural precipitation. In selected environments with relatively less stable rainfall patterns it would be desirable to evaluate intermaturity varietal blends of different proportions.

Table 9. Evaluation of intercropped maize, Kharif, 1985

Variety	Grain yield (kg/ha) Dholi[a]	Dholi[b]	Relative yield[c] (%)	Grain yield (kg/ha) Kolhapur[a]	Kolhapur[d]	Relative yield[c] (%)
Maize Suwan (Y) /Deccan 103	16.3	16.6	102	57.3	53.3	93
Vijay	15.0	12.8	85	38.0	34.7	91
Ganga-5	13.4	13.1	98	46.7	39.3	84
J 54 (ZFS4)	12.9	12.0	93	39.3	39.3	100
Ganga Safed-2	15.1	15.7	104	37.3	36.0	97
Ageti-76	13.5	12.4	92	39.3	34.7	88
J 684	14.4	9.8	68	41.3	36.0	87
EH 21 71	16.2	16.5	102	39.3	37.0	94
J 2021	12.8	14.8	116	40.7	39.3	97
EH 401075	12.9	12.7	98	50.0	40.7	81
A-68	15.9	12.5	79	37.3	34.0	91
J 3022	17.5	11.8	67	22.7	22.0	97
UPB 741 (Poonch)	13.0	19.8	91	37.3	25.3	68
UPB 741 (Pantnagar)	9.8	9.5	97	32.7	25.3	77
VL 42	12.1	10.4	86	24.0	22.0	92
Diara-3	10.7	9.6	90	18.0	18.0	100
D-765	10.2	8.1	79	20.7	18.0	87
MCU 508/D-823	10.9	10.0	92	22.7	23.3	103
EV III CD(Y)	15.7	16.5	105	17.3	16.0	92
Suwan (Y) Local	13.6	12.5	92	33.8	31.3	93

[a]Yield of maize in pure stand.

[b]Yield of maize intercropped with groundnut.

[c]Relative yield = yield of intercropped maize as percentage of maize yield in pure stand.

[d]Yield of maize intercropped with moong.

Fertilizer use--Past studies have shown that maize varieties of different maturity groups respond favorably to the application of fertilizer. However, level of response was observed to be a varietal trait. The response of full-season varieties was better than that of short-duration types. Studies also showed that application of nitrogen in three unequal doses (25% at sowing, 50% at the knee-high stage, and 25% at flag-leaf emergence) is better than other schedules. Using three unequal split applications helped improve nitrogen use efficiency. Beemcake (Azadirachta indica) and a few other nitrification inhibitors have not been found to be very promising. Zinc application has been shown to be particularly valuable under stress conditions.

Sowing date and plant population--Sowing the crop at the optimum time and achieving the optimum plant population are two very important nonmonetary inputs. Time of sowing is obviously determined by the actual date when rainfall is adequate, but where the crop can be sown in dry soil and one light irrigation can be provided for germination, it is desirable to sow 7-10 days before it rains. A plant population of 65,000-70,000 at harvest is considered necessary. To overcome mortality caused by various factors, overplanting by 10% is frequently considered necessary. Spacing of 60 x 25 or 75 x 20 cm is considered more convenient than using narrrow row spacing, since it facilitates cultivation by bullock or tractor.

Mulches--Studies on using straw mulch to conserve soil moisture have given varied results. In medium to heavy soils during years of heavy rainfall, the maize crop suffered from waterlogging. Moreover, in very light soils when precipitation was low, white ants were a serious problem. Using in situ mulches and burying them at the most appropriate time, particularly with cowpea, has given encouraging results.

Intercropping short-duration varieties--Past studies have shown that short-duration varieties of oilseeds and pulses can be successfully intercropped with maize without affecting the maize yield. Among oilseeds, the best results were obtained with groundnuts; among pulses, soybeans, moong, urd, and cowpeas gave good returns. Under severe moisture stress, intercropping with guar and short-duration leaf vegetables also gave encouraging results.

Weeds--Although weed control can be done through intercultivation, the operation is laborious and cannot be undertaken in years when the rains continue for a long time. Atrazine and simazine applied at 1.0-1.5 kg/ha as a pre-emergence herbicide gave good weed control for three to five weeks. Afterwards weeds can be controlled by one or two intercultivation operations.

Seed soaking--Recent studies have shown that using seed soaked in lukewarm water overnight hastened germination and gave higher yields, particularly when the temperature at sowing time was low. This procedure was observed to be of particular value during winter and in Zone I areas.

Supersorbents--A special maize starch, marketed under the name "Jalshakti," has a high water-absorbing capacity and was evaluated as a soil dressing and seed coat. Initial studies at five locations gave encouraging results. Additional data are necessary to establish the utility of these procedures.

Controlling Major Insect Pests and Diseases

Breeding for resistance to insects and diseases forms an integral part of the crop improvement program. The major aim has been to confer a high level of resistance on the more productive hybrids and composites recommended for cultivation. Techniques for mass rearing of insects, producing inoculum in the laboratory, field inoculation, and rating plant injury have been developed. Sources of resistance to most diseases and pests of local importance have been identified and suitably introgressed into composites and pools under improvement.

Schedules for chemical control of borers and foliar and stalk rots have also been studied, and suitable, economically viable recommendations have been made for commercial crop production.

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Discussion

M. Saleem: When breeding for very short season varieties, do you consider plant density in yield trials when making comparisons with the original population? When breeding maize for high elevations, do you breed in the area of adaptation?

J. Singh: In one study with Diara composite (cycle 0 versus cycle 5) there was no difference in maturity. However, the cycle 5 materials were, on the average, slightly taller and had superior yields. An earlier study showed the response of different maturity groups to different plant population densities. The optimum level was 6.0-6.5 plants/m^2. We have devised a wheel-spoke design to select for varieties showing tolerance to plant density stress.

We have undertaken a breeding, testing, and seed production program for varieties for high elevations. Such an approach is necessary to avoid any major genetic drift and to select appropriate genotypes for high elevation environments.

C. Chutkaew: Have you compared unit selection with other breeding procedures? Would you kindly give the names of materials you have developed through unit selection?

J. Singh: Materials developed during a specific period from various population improvement programs are evaluated together in the national coordinated program. Through these tests six different multiple convergent units (MCU508, MCU501, MCU507 of D maturity, MCU314 of B maturity, and MCU216 and MCU 204 of A maturity) have been identified for release. Moreover, two comprehensive studies have been done to provide direct comparisons.

M.M. Lantin: In your half-sib selection, what kind of tester are you using? Did you use an outside tester?

J. Singh: In our program, balanced seed of all selected progenies serves as the male parent. Generally seed of 60-70% of the selected progenies is bulked, while all the selected progenies are included as female entries.

D.L. Winkelmann: You comment on the advantages of blending maturity classes and observed higher yields from blends than from pure seedings. What is your explanation for this result?

J. Singh: It should be mentioned that intermaturity blends were evaluated under rainfed stress environments. Under irrigated or favorable conditions, full-season varieties are known to do better than early to medium-maturity varieties. Using two-maturity blends is a means of realizing higher yields if there is more rain. However, short-duration varieties certainly provide better yield stability, though their mean performance is likely to be lower than optimum when intermaturity blends are used. Blends provide a better buffering ability than does the sole variety under stress. Selection of component varieties and their relative proportion is of considerable importance in realizing high, stable yields.

R.L. Paliwal: What kind of germplasm is more suitable for winter planting? Can you categorize germplasm presently available in India for the development of hybrid varieties for the regular season or the winter season?

J. Singh: Based on our experience, it is evident that subtropical source materials are more favorable. By and large, India x subtropical materials are useful in the kharif season and subtropical x temperate germplasm is more useful in the winter season. Temperate germplasm by itself has not been found to perform better in most areas, although in some parts of the hills region above 32^{o}N latitude temperate materials hold some promise.

Definite evidence of genotype x season interaction has been recorded. This is well illustrated by the hybrid Ganga 2, which has done well in the monsoon season, and the hybrid Hi-starch, which has done well in the winter season. On the other hand, such hybrids as Ganga 5, Ganga 9, and Deccan 103 have performed well in both seasons.

R.L. Paliwal: Is cold tolerance an important trait for winter planting materials? If so, is any selection being done for this trait?

J. Singh: There is a need to incorporate cold tolerance into materials that are likely to be used for the study in Punjab, Halyana, and Rajasthan. In most other studies in peninsular India, frost is not a problem. Problems with frost can be partially overcome by delaying sowing until mid-November, since frost can be tolerated by seedlings: plants quickly resume growth and recover their foliage when growing conditions return to normal in January.

K.K. Lal: What is the per-day yield level you get in maturity group D?

J. Singh: Yields vary substantially with locations and growing season. However, in the mainland grain yields of 2500-3000 kg/ha have been obtained, and these very early varieties mature in 75-80 days.

K.K. Lal: Did you compare the unit selection via half-sib or S_1 selection method in terms of genetic gain?

J. Singh: We have been evaluating the efficiency of unit selection and half-sib selection. Both methods have their own merits. It will be more appropriate to combine half-sib and unit selection to optimize gains through selection and select cultivars that would be superior for a set of desired traits.

K.K. Lal: What about the genetic base when a unit is used directly as a commercial cultivar?

J. Singh: The whole population should have a good level of genetic variability with a substantial portion of additive variance. Considerations necessary in any other intrapopulation improvement program would hold true.

K.K. Lal: What should the heterotic level be in the case of a unit hybrid? I think the 15% reported is too low.

J. Singh: More valid comparisons would be with commercial hybrids. However, I agree that the hybrid should have at least 15% superiority to cover the extra cost of seed production.

Nepal

V.P. Sharma and K.K. Lal, National Maize Development Program

Maize occupies 573,430 ha of the total cultivated area in Nepal, about 23% of the total arable land, and the average yield is 1480 kg/ha. The area covered by improved maize is approximately 30% of the total maize area. Maize is the second most important cereal crop in Nepal and is a staple food in the hills, where approximately 8.5 million of Nepal's 16 million people live. Among the three major agroclimatic zones (high hills, mid-hills, and terai) the average maize area is 191,143 ha; average annual production is 250,387 t.

Although the total area planted to maize has increased, production has declined (Table 1). The decline may be attributed to unpredictable monsoon rains, the erosion of topsoil because of poorly constructed terraces, the use of marginal land for maize production, and very low use of fertilizers, herbicides, and insecticides.

In the hills and mountains, over 90% of the maize produced is consumed as roti (flat bread), dhido (thick porridge made of maize flour), chyakhla (grits, cooked like rice), roasted or popped maize kernels, and as roasted green ears.

Table 1. Maize area, production, and average yield in Nepal

Year	Area (000 ha)	Production (000 Mt)	Average yield (kg/ha)
1977	445	797	1790
1978	445	740	1664
1979	454	743	1635
1980	432	554	1281
1981	457	743	1629
1982	475	752	1581
1983	511	718	1410
1984	479	698	1510
1985	556	766	1420
1986	573	851	1480

Nepalese farmers prefer varieties with hard flint kernels. Kernel color preference varies from white flints in the west and east to yellow flints in the central regions. However, in the high hills farmers generally do not care for the mixture of white and yellow kernels. Farmers prefer early maturing varieties with tight husk cover and short plant type. Considering all of these factors, the NMDP is endeavoring to develop broadly adapted varieties with adequate genetic variability that can be grown under a reasonable range of agroclimatic environments.

In 1965 Dr. E.W. Sprague, then coordinator of the Rockefeller Foundation Maize Development Program for Southeast Asia, was invited by the Department of Agriculture to examine the possibility of launching a maize development program in Nepal. He advised the Department of Agriculture to establish a coordinated maize development program as an independent entity solely for maize improvement in the Department of Agriculture. Accordingly, the NMDP came into existence in 1972, headquartered at Rampur in Chitwan District, situated in the inner terai (lowland) belt of Nepal. Before the coordinated program was established, maize research was done by different technical divisions situated at Khumaltar in Kathmandu valley under the leadership of the Agricultural Botany Division.

Breeding

Prior to 1965 some varieties (Amarillo de Cuba, Cubano Flint, and Francisco Flint) had been introduced, but although they were high yielding they remained unpopular with farmers because they matured late. In 1965 some varietal crosses and composites obtained through IACP, India, were tested on farms in Khumaltar, Rampur, and Nepalgunj. Three varieties--Composite J for terai and inner terai (lower elevations); Antigua 2D x Guatemalan for the hills (1500 m); and Antigua group 2 x Guatemalen for higher elevations (2000 m and above)--were recommended to meet the immediate demand of farmers. These exotic materials were later named Rampur Yellow, Khumal Yellow, and Kakani Yellow, respectively.

No doubt, those varieties were high yielding, but they also possessed such undesirable characteristics as a high percentage of cobs with bare tips, late maturity, and tall plant type. These problems were lessened through half-sib and mass selection methods. The composite variety Hetauda was recommended for general cultivation in 1972 after two years of testing at different research stations as well as in farmers' fields. This variety was developed by compositing some unknown varieties from Pakistan, three Nepalese recommended varieties, and one Hetauda local. The variety was originally recommended for terai and low hill areas but is popular today in the higher hills as well.

The downy mildew disease of maize was reported in Nepal for the first time by S. Moin Shah in 1966. Even local varieties were found to be susceptible to the disease, and the NMDP began research for developing resistant varieties. A few progeny testing trials of different downy mildew-resistant full-sib families were received from Thailand and the Philippines. Some varietal trials involving progeny testing were also sent by IACP, Thailand. In due course, Thai Composite (later named Rampur composite) and Philippine DMR-2 (later called Sarlahi Seto) were found to be resistant and in 1975, after extensive testing, were recommended to farmers.

Since 1972 the program has received CIMMYT materials in Experimental Varietal Trials (EVTs), Elite Experimental Varietal Trials (ELVTs), and International Progeny Testing Trials (IPTTs). From these trials the NMDP has released only three varieties. Rampur 7434, named Janaki Makai, was released in 1979. The early maturing variety Arun-2 is the most popular among farmers because it fits well into mixed cropping and sequential cropping systems. Both of these varieties are grown throughout the country. Amarillo del Bajio (Makalu-2) was released in 1985 for small areas in the eastern and western hill regions.

Populations--Presently the program maintains seven breeding populations to develop varieties for Nepal's agroclimatic regions of the country. The three major agroclimatic zones are:

* High altitude (2000 m and above)
* Midaltitude (1500 m)
* Terai and inner terai (lower altitude with a subtropical climate)

The populations include:

* Ganesh-2 (for high hills): Half-sib families of yellow flint highland materials
* Manakamana-1: Half-sib families of white flint materials for midaltitude subtropical areas
* Manakamana-2: Half-sib families of a yellow flint, stalk rot-resistant subtropical population, adapted to midaltitude areas
* Rampur-1: Half-sib families of white flint, subtropical material, adapted to low altitude and terai areas

* Rampur-2: Half-sib families of yellow flint. downy mildew-resistant material. adapted to the terai and inner terai belt

* Arun-1: Half-sib families of white flint. early maturing type. suitable for mixed or sequential cropping systems

* Arun-4: Half-sib families of yellow flint, early maturing type. suitable for mixed or sequential cropping systems

These populations were composited from local materials and different types of similar germplasm obtained from various cooperating agencies. The half-sib method of population improvement is used.

The NMDP will release one variety each from the Manakamana-1 and Rampur-2 in the near future.

Varietal testing procedure--There are four steps in the testing procedure:

* Breeding nursery: All exotic or experimental varieties are placed in this nursery, which is usually sent to three breeding stations situated at different elevations. Better genotypes are placed in NMDP trials. and some are used for crossing.

* NMDP varietal trial: This trial is grown at 10-12 locations differing in elevation and rainfall.

* Farmers' field varietal trial: Elite materials are taken fron NMDP trials to form this trial. which is planted in farmers' fields and coordinated by station personnel and production agronomists from headquarters. Field days are arranged to obtain farmers' reactions to the materials.

* Minikit demonstration: This is another means of familiarizing farmers with new materials. Yield data and farmers' responses are obtained from this demonstration. Minikits (prepared by the NMDP) are grown in 500-m^2 plots and consist of 1/2 kg seed of each of two varieties. 5 kg urea for side dressing, granular insecticide for controlling stem borers. a maize production booklet. and feedback cards. Kits are delivered to Agricultural Development Offices in the districts by the NMDP. which also handles

distribution to farmers. Feedback cards, signed by the farmer, the junior technical assistant posted in the village, and the agricultural development officer, are sent to the NMDP after harvest. Handling costs up to the district headquarters are paid by the NMDP.

Foundation seed of varieties judged to be superior based on their performance in trials and the response of farmers is produced, and its release must then be approved by the Variety Release Committee. Varieties recommended to Nepalese farmers for general cultivation have several salient features (Table 2).

Multilocation trials are conducted at 11 farms and stations (Table 3). Because of significant genotype x environment interactions (Table 4), the main breeding stations are situated in different agroclimatic zones of the country. At Rampur, which is the headquarters station, maize can be grown throughout the year, which facilitates generating material and advancing the breeding cycle.

Table 2. Features of varieties recommended to Nepalese farmers

Variety	Year recommended	Grain color	Maturity (days)	Height (cm)	Yield (t/ha)	Area of cultivation
Kakani Yellow	1965	Orange yellow	190-200	220-225	4-6	Elevations over 2,000 m
Khumal Yellow	1965	Orange yellow	115-125	205-210	4-6	Midaltitude, 1,500 m
Rampur Yellow	1965	Bright yellow	100-110	230-235	4-5	Terai and inner terai
Rampur composite[a]	1975	Orange yellow with whitish spot	100-110	210-220	4-6	Terai and inner terai
Hetauda composite	1971	Yellow	110-120	220-225	3-4	Inner terai
Sharlahi[a] Seto	1975	White	110-120	260-265	3-4	Terai and hills
Janaki[b] Maka	1979	White	110-120	195-200	5-6	Terai and hills
Arun-2[c]	1983	Yellow	80-90	190-200	2-3	Terai and hills

[a] Resistant to downy mildew.

[b] For winter cultivation in terai.

[c] Suitable for multiple cropping.

Table 3. Multilocational trial sites in Nepal

Research station	Elevation (masl)	Annual rainfall (mm)
Doti	620	900
Jumla	2387	600
Nepalganj	190	1300
Lumle	1520	5600
Rampur	228	2000
Khairenitar	525	--
Kabhre	1700	--
Khumaltar	1360	1200
Kakani	1858	2600
Pakhribas	1227	800
Tarahara	200	1700

Table 4. Results of a National Maize Development Program variety trial, 1985

Variety	Grain yield (kg/ha) at various locations										
	1	2	3	4	5	6	7	8	9	10	Mean
Ganesh-2	4.7	3.5	3.2	7.1	5.5	2.7	2.7	4.8	3.2	2.9	4.0
Manakamana-2	3.8	3.4	3.1	7.5	5.4	2.0	3.4	3.9	2.8	3.3	3.9
Manakamana-1	4.6	4.1	3.5	7.1	6.3	2.3	2.2	5.5	3.6	2.9	4.2
Rampur-2	3.9	3.4	3.4	6.5	5.9	2.2	2.2	4.3	2.9	2.6	3.7
Arun-4	3.1	3.2	3.4	5.9	4.3	2.6	3.2	4.4	2.7	2.7	3.6
Arun-1	3.0	3.3	2.6	5.7	6.0	2.2	2.8	3.3	3.0	2.9	3.5
Pioneer 6181	3.4	1.7	2.7	2.1	6.4	2.3	1.5	2.5	1.2	2.9	2.7
Khumal Yellow	3.0	4.2	3.5	3.3	5.8	2.3	2.0	3.0	2.3	2.8	3.2
Rampur comp.	4.3	3.5	3.2	7.3	5.9	2.7	2.1	5.2	2.7	2.7	4.0
Arun-2	3.7	3.0	3.1	6.0	5.7	2.5	2.5	4.2	3.2	3.0	3.7
Farmers' var.	4.8	3.5	2.0	2.7	5.8	3.8	2.4	3.8	2.8	2.8	3.4
C.V. (%)	27	17	16	30	15	30	--	29	17	21	

Agronomy Research

We have been unable to make as much progress in agronomic research as we have made in varietal testing and related breeding activities. However, we are trying to alter the situation by starting production-oriented research to help farmers raise production.

Cropping pattern trials, for which we have received bilateral grants from other agencies, receive the most emphasis. Results of those trials indicate that the highest maize yields are obtained from winter plantings (September in the inner terai and October in the terai). The proper time for planting maize in the monsoon season appears to be from mid-April to mid-May. From the trial results, it appears that the proper plant density is approximately 53,000 plants/ha sown in lines 75 cm apart at 25 cm spacing using a hand planter or sowing behind the plow. This observation has been confirmed in trials on farmers' fields. Weed control studies indicate that spraying with Atrazine before emergence is comparable to hand-weeding.

Fertilizer trials at the research station and on farmers' fields show optimum fertilizer levels to be 90:45:45 kg N, P_2O_5, and K_2O/ha for the winter crop and 45-60:30:30 kg N, P_2O_5, and K_2O/ha for the monsoon crop. However, some on-farm research has failed to show a definite response to applications of phosphorus and potassium.

Fertilizer trials also indicated an increasing problem of zinc deficiency, especially in the terai and inner terai. Various research trials have shown that the highest yields are obtained when nitrogen is applied in split applications, half as basal fertilizer and the other half as a sidedressing when maize is at the knee-high stage. On-farm trials showed that to avoid unfavorable soil moisture regimes a single sidedressing of 30-45 kg N/ha applied at the knee-high stage is useful for rainfed conditions, where compost is used as the basal dose.

Diamond demonstration trials (Figure 1) in farmers' fields clearly demonstrate the profitability of improved varieties and cultural practices over the farmers' own maize varieties and production practices.

Maize Diseases

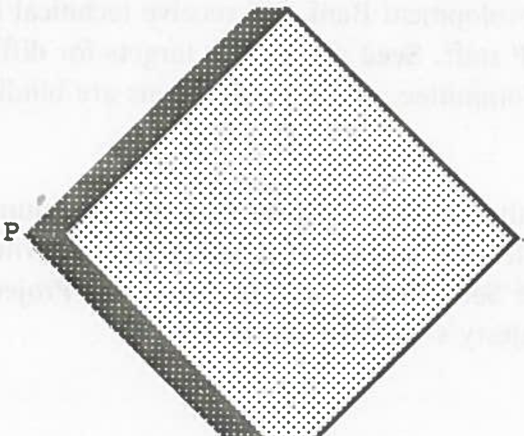
Surveys done in 1977 and 1980 indicate that the major diseases of maize in Nepal are:

- Ear rot
- Stalk rot
- Downy mildew
- Foliar diseases:
  - Common rust
  - Leptosphaeria leaf blight
  - Curvularia leaf spot
  - Northern and southern leaf blight

Among the various organisms that cause ear rot. Fusarium moniliforme is the most prevalent and destructive. Ear rot is common mostly in the higher hills. and damage is estimated to be very high since the infection ranges from 40 to 80% and even higher in some varieties of maize. In varietal investigation trials. Kakani local showed a high degree of resistance to the pathogen. Chemical control of ear rot was tried for three years: Dithame M-45 proved to be most effective but had to be sprayed at 2.5-3 g/l at 15-day intervals from silking until harvest--a treatment that was not economical.

Stalk rot diseases have been reported since 1967-68, and several epiphytotics have been observed. Bacterial stalk rot. caused by Erwinia carotovora. is the most destructive in the terai and inner terai; Pythium aphanidermatum is prevalent in the higher hills. No chemical was found to combat the pathogen effectively. and no resistant varieties have been identified. However. to minimize the disease several practices have been recommended: sanitation. borer control. cultural practices that minimize plant injury and waterlogging, and the maintenance of optimum plant population.

Since downy mildew was first reported in 1966. three species of Sclerospora have been identified. Maximum infection occurs when maize is sown between the 15th and 30th of June. Rampur composite and Sarlahi Seto varieties are relatively resistant to the pathogen and have been recommended to farmers.



F = Farmer
I = Improved
V = Variety
P = Practice

Figure 1. Diamond demonstration trial.

Of the numerous foliar diseases identified in Nepal, not all are economically important, although some reduce maize yields.

Insect Pests

Entomological studies indicate that a number of insects are injurious to maize in Nepal. Some cause poor germination, whereas others reduce plant vigor and cause significant yield reductions. A few insects are responsible for postharvest losses. Armyworm larvae are the sole defoliator of maize in almost all of the hilly areas of the country, and stem borer causes heavy losses from the terai to the mid-hills region.

Yield losses of up to 1965 kg/ha were reported in the yellow variety Khumal at Khumaltar under infestation with different insect pests. The cost-benefit ratio was 1:4. Sevin 4% granules and Furadan 3% granules control borer damage if the insecticide is applied at a rate of two to three granules per plant in the whorls. Thiodan (125 ppm) and Sevin (250 ppm) were found to be good grain protectants against Sitophylus oryzae and Sitotroga cerealella during the entire season. Germination was unaffected.

Seed Production Program

Once a variety is released, the NMDP is responsible for producing foundation seed. The foundation seed is supplied to the Agricultural Input Corporation (AIC), which produces certified seed. No private seed industry exists in Nepal, so certified seed is produced by farmers under contract to AIC. Farmers obtain production loans from the Agricultural Development Bank and receive technical help from the AIC seed division and NMDP staff. Seed production targets for different crops are fixed by the Central Seed Committee, and their decisions are binding to all agencies concerned.

Seed is bought by the AIC and farmers receive a premium over the market price based on a favorable seed inspection report and other criteria. Seed inspection is done by staff of the Seed Testing and Improvement Project, Agricultural Botany Division of His Majesty's Government of Nepal.

Discussion

K. Khan: Are the varieties Kakani Yellow and Kakani Improved grain or fodder varieties? Do they mature at high elevations (2000 masl)?

V.P. Sharma: Both are grain varieties, and the maturity period is from 6 to 10 months, depending on the elevation at which the material is grown.

C. Chutkaew: Since in Nepal you have hills as well as plains, have you tried to obtain from two kinds of materials (for the hills and for the plains) a genotype adapted to both areas?

V.P. Sharma: In general, maize for the monsoon season shows a very high germplasm x environment interaction that is not shown by winter maize varieties. However, winter plantings are possible only at lower altitudes, and any variety may be grown successfully. Arun-2, an early maturing variety, is grown throughout the country in the monsoon season. Khumal Yellow, recommended for the mid-hills area, grows well at lower elevations during the monsoon season. Rampur composite, recommended for lower elevations, grows well in the mid-hills area as well.

J. Singh: You have mentioned that Kakani Local is resistant to stalk rot. Are there other varieties, local or exotic, that have shown resistance?

V.P. Sharma: Kakani local is not resistant to stalk rot but to ear rot. We have no variety that is resistant to stalk rot.

Pakistan

M. Aslam and M.Q. Chatha, National Agricultural Research Center; M. Saleem and K. Khan, Cereals Crop Research Institute; and M. Afzal, Maize and Millets Research Institute

Maize, being the highest yielding cereal crop in the world, is of paramount importance in countries like Pakistan where population has already outstripped available food supplies. The crop was introduced in this part of the world at the beginning of the 16th century by European traders, but its importance for solving Pakistan's food problems was not appreciated until 1912, when maize research began with the establishment of the Agriculture Research Institute at Tarnab.

Several campaigns to increase maize area and production were organized by the government before and after independence. Germplasm was introduced from abroad (Boons County White, Rhode Island, and Pride of Salina) and collected locally, especially from Sawabi, Hazara, and other northern areas. During 1955 a seed production scheme was started, using parental lines of several hybrids brought into Pakistan from the west with help from USAID. But these varieties were late maturing, did not fit into the farmers' cropping pattern, and were susceptible to foliar diseases. In 1962 an accelerated maize and millet improvement program was started, and the development of synthetic/composites was initiated in collaboration with the Ford Foundation. Some work on hybrids was also undertaken, but was abandoned because of difficulties with seed production.

In 1971 two maize and millets research institutes were opened, one at Pirsabak and the other at Yousafwala. Their major task was the development of open-pollinated maize varieties in collaboration with CIMMYT. A coordinated research program for maize and millet was initiated in 1975 by the Pakistan Agricultural Research Council (PARC) to coordinate research done in different provinces.

Maize is cultivated in Pakistan on about 0.8 million hectares, with total production reaching a little over 1 million tons. Average yields are about 1.3 t/ha. Government statistics reveal that since 1970-71 the area planted to maize has increased 15% and production has risen 41% (Table 1). The increase in production is mostly attributed to the increased area, though improved varieties and better crop management practices have also contributed to higher production.

Maize is cultivated more in northern Pakistan, especially in Peshawar, Hazara, and Makaland Divisions, where about half of the total area planted to maize is found. The areas ranked next in importance are Rawalpindi, Faisalabad, and Multan Divisions. It is apparent that Punjab and the Northwest Frontier Province (NWFP) are the major maize-producing provinces, together accounting for about 95% of total production. Maize is planted on the plains of Sind. almost at sea level. as well as in the northern mountains. In the canal colonies of the Punjab. two maize crops can be grown in a year, during the spring and again in summer. In the irrigated areas of lower Sind where winter is mild. three crops of maize can be produced in a year, allowing farmers to maximise the use of land and water resources.

Because of the intensification and agroecological distribution of the crop. several institutions and units have been working on maize (Table 2). The major objectives of their research are:

* Development/evaluation of varieties of broad and specific adaptability. high yield potential, drought tolerance. and disease resistance
* Introduction and testing of new germplasm and released varieties from international and national institutes
* Development of quality protein maize varieties
* Breeding for the stay-green character
* On-farm testing and demonstration of new materials through simple trials designed to determine the constraints to obtaining high yields under conditions on farmers' fields
* Screening and developing varieties for hilly areas

Table 1. Area, production, and yield of maize in Pakistan, 1975-84

Year	Area (000 ha)	Production (000 t)	Yield (kg/ha)
1975	613.7	746.9	1217
1976	620.0	802.5	1291
1977	624.0	763.7	1227
1978	656.1	820.9	1251
1979	650.2	798.6	1228
1980	701.1	875.2	1248
1981	744.7	946.6	1271
1982	739.0	930.0	1259
1983	790.0	1005.0	1273
1984	798.0	1014.0	1270

Source: Agricultural Statistics of Pakistan, 1984. Food and Agricultural Division, Islamabad.

Considering the needs of different areas and agroecological zones, researchers have developed several high-yielding varieties that have been released to farmers. A number of varieties developed in the past 10 to 12 years (Tables 3 and 4) have shown great potential in different parts of the country. The range of adaptability and performance of newly developed varieties is tested at several locations throughout the country in a national testing program. Results from those trials provide breeders with ideas and guidelines for using germplasm available from their counterparts in other parts of the country, and also facilitate the identification of potential areas for making recommendations (Figure 1).

Information on the dissemination and adoption of these varieties by farmers varies. According to one survey (unpublished Ph.D. dissertation), about 40% of the area in NWFP and 60% in Punjab is planted to improved varieties (Table 5). However, a recent survey by agricultural researchers indicates that 10-12% of the area in NWFP and 57% of the area in Punjab is planted to improved, high-yielding varieties. Despite the variation in these figures, it is nevertheless true that although the area planted to improved varieties has gradually increased, the yield per unit of land has remained almost static. This is because improved varieties have little impact on production unless they are grown using improved technology.

Table 2. Maize research institutes/units in Pakistan

Institution	Location
National Agricultural Research Centre (NARC)	Islamabad
Cereal Crops Research Institute (CCRI)	Pirsabak, NWFP[a]
Maize and Millets Research Institute (MMRI)	Sahiwal, Punjab
Mona Reclamation Experimental Project (MREP)	Bhalwal, Punjab
Agricultural Research Station (ARS)	Dadu, Sind Bagh, AJK[b] Baluchistan

[a] Northwest Frontier Province.

[b] Azad Jammu and Kashmir.

Table 3. Maize varieties released in Pakistan, 1973-82

Variety	Year of release	Description	Area of adoption
Akbar	1973	Full sib Yellow semident	Plains of Punjab and Sind
Sadaf	1976	Full sib White semident	Foot Hill Plateau, northern and central Punjab
Sultan[a]	--	Full sib Yellow semident	Central NWFP, Punjab, and parts of Sind
Composite-15[a]	--	Full sib White dent	Central NWFP, Punjab, and parts of Sind
Sunehri	--	Mass selection Yellow semident	Central NWFP, Punjab, and parts of Sind
Sarhad (Y)	1972	Full sib Yellow semident	Lower and central NWFP and Punjab
Shaheen	1974	S_1 selection White semident	High elevations
Zia	1974	Mass selection White semident	Northern mountains and northern Punjab
Changez	1974	Mass selection White semident	Throughout NWFP, plains of Punjab, and Sind
Sarhad White	1977	Full sib White semident	NWFP plains, AJK, and northern Punjab
Azam	1982	Mass selection White semident	NWFP and northern Punjab
Munawar	1982	Full sib White semident	AJK
Kashmir Gold	1982	Full sib Yellow dent	AJK
Gauher[a]	--	Mass selection White flint	NWFP, northern Punjab, and AJK

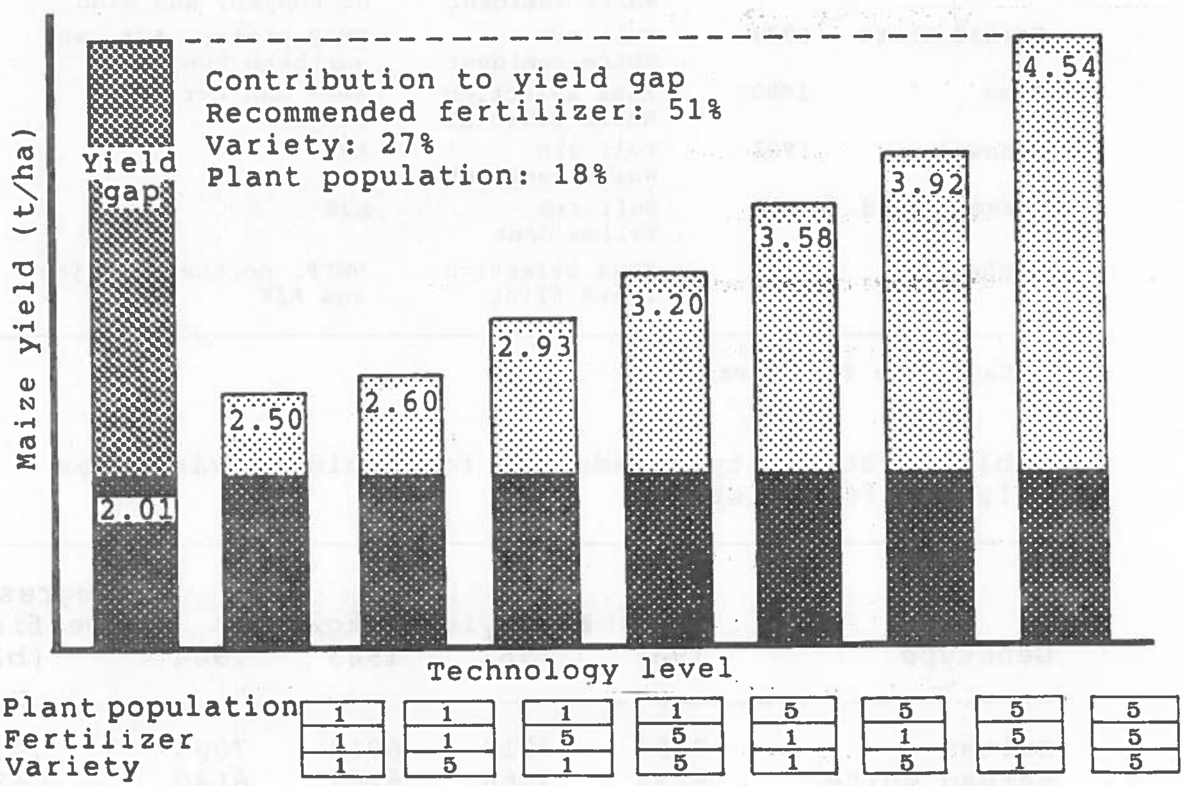
[a] Candidate for release.

Table 4. Stability parameters for yield of varieties released in Pakistan

Genotype	Mean yield (kg/ha) 1981	1982	1983	1984	Regression coefficient (b)
Sultan	7354	7013	6912	7093	.95
Sarhad White	6294	5860	6267	6140	.49
Pirsabak-7734	7737	7305	6152	7064	.78
Yousafwala 7845	6542	7552	6532	6875	.64

Table 5. Percentage of total maize area sown to high-yielding varieties, Punjab and NWFP, 1972-81

Year	Punjab	NWFP	Total
1972	14	9	11.3
1973	17	10	13.1
1974	20	13	16.1
1975	25	15	19.5
1976	30	19	24.3
1977	35	21	27.6
1978	41	26	32.9
1979	46	29	37.3
1980	53	35	43.7
1981	60	40	49.7



Fertilizer level
1=Farmers', 60-45-0/ha
5=Recommended, 120-60-60/ha

Variety
1=Swabi white
5=Sarhad white

Plant population
1=100,000/ha
5=55,000/ha

Figure 1. Maize yields at various levels of technology (Mardan, 1982).
Source: A.R.I. Tarnab.

Agronomic research on experiment stations promises to help reduce the gap between actual and potential production levels. This will not be done, however, until the package of technology is transferred to and adopted by growers. Technologies developed on stations under controlled conditions are of little value unless they are adaptable to and practical under farmers' circumstances.

The agronomic and economic circumstances of producers must be considered, and the on-farm research program is making an effort to test technologies under farmers' conditions and to verify results obtained on experimental stations in areas for which the technology has been developed. Different types of farmer-managed trials are conducted on farmers' fields to demonstrate the advantages of adopting improved varieties in conjunction with improved management practices (Table 6).

It has been very difficult to get farmers to adopt the set of recommendations. For that reason a simpler and more effective system is being tried in which the effect of any single factor contributing to improved production is demonstrated through trials that are superimposed on farmers' fields. One example of this procedure is the use of chemical weed control. In the Pothowar area of northern Punjab, continuous monsoon rains make it almost impossible to weed maize fields manually at the

Table 6. Results of verification trials in Pakistan, 1985

	Complete technology	Intermediate technology	Farmers' practice
Adjusted grain yield (kg/ha)	4997	3956	1329
Field price (Rupees)	8328	5934	1993
Gross benefit (Rupees/ha)	6256	4945	1661
Variable costs (Rupees)			
Fertilizer	968	645	316
Transport of fertilizer	15	10	5
Primextra (2 l FM/ha)	280	--	--
Cost of application	20	--	--
Rental of sprayer	50	--	--
Hand-weeding (15 man-days)	--	300	--
Seel (two)	--	--	100
Furadan (16 kg/ha)	400	400	--
Total	1733	1355	421
Net benefit	4523	3590	1240
MMR (%)	246	252	--

correct time. Chemical herbicides have proved most effective in this area: results from experiment station research have revealed that the use of herbicide has a significant impact on productivity and, hence, on net returns (Table 7). The results from trials superimposed on farmers' fields have indicated a tremendous effect on different yield components.

Varieties that possess high production potential and are adapted to different agroecological conditions are available, as is a set of agronomic recommendations suited to farmers' socioeconomic conditions. The major constraint to raising production is unavailability of improved seed. Presently about 500 t of hybrid seed and 1200 t of seed of open-pollinated varieties are produced by public and private agencies to meet a requirement of 40,000 t of seed. Other major constraints to increasing production are:

Research constraints:

* Lack of technical personnel
* Ineffective extension system
* Lack of adoption of improved varieties and production technology
* Use of maize plantings both for grain and fodder production

Table 7. Weed control trial in maize, Islamabad Capital Territory, 1983-84

Treatment	Mean yield (t/ha)	Variable cost (Rs/ha)	Net benefit (Rs/ha)	MRR (%)
No weeding	2.41 c	–	3012	
Hand-weeding	3.63 b	750	4537	
Primextra (1.5 l a.i./ha)	4.00 a	260	5000	754
Primextra (3.0 l a.i./ha)	4.66 b	470	5825	393
Price of maize grain		Rs 60/40 kg		
Harvesting, shelling, and transportation costs		Rs 10/40 kg		
Cost of herbicide		Rs 140/l		
Herbicide application cost		1 man-day/ha		
Rental of sprayer		Rs 25/ha		
Hand-weeding		20 man-days/ha		
1 man-day		Rs 25		

Policy constraints:

* Cultivation of maize as a subsistence crop
* Lack of proper procurement and marketing systems
* Lack of credit facilities, especially for small-scale farmers

Discussion

J.M. Corpuz: Are your verification trials done under farmers' conditions? If so, which parameters determine when a technology is ready for dissemination to farmers?

M. Aslam: Verification trials are conducted under farmers' conditions in their fields. Everything is managed by the farmer, except for the treatments we recommend. In determining when a variety is ready for dissemination to farmers, we work with social scientists to identify priorities and gather baseline data. We also conduct follow-up surveys to document farmers' reactions and acceptance of recommendations. More recently, farmer self-help groups have been formed as models for testing the feasibility of moving technology from on-farm trials into a limited but relatively large farming community. The private sector and government extension services are introduced to effective technological innovations through working models represented by the farmer self-help groups.

C. Chutkaew: Have you tried to breed for stress environments? If so, can you name the varieties used, sources of germplasm, and the length of time it has taken you to do this work?

M. Aslam: We are doing some selection for salt tolerance because of salinity problems, and the variety Sultan has shown promise so far. It has been developed by crosssing local germplasm to some tropical material from CIMMYT. So far we have done a pot study.

Philippines

M.M. Lantin, Institute of Plant Breeding; L.P. Oliva, University of Southern Mindanao; G.R. Minguez, National Food and Agriculture Council; and J.M. Corpuz, Ministry of Food and Agriculture

Maize (Zea mays L.) is one of the most important crops grown in the Philippines. where it is consumed by about 20% of the population in the form of white maize grits. More than half of the country's total maize output is used as animal feed; yellow maize is preferred by the feed milling industry. Maize is also used in the manufacture of starch and starch derivatives. syrup. and oil. Thus. as food for human consumption, animal feed. and raw material for industry. maize is one of the most valuable cereal grains. This paper gives an overview of maize research and development programs in the Philippines.

Production, Area, and Yield

Between 1972-73 and 1984-85. maize production grew at an annual average rate of 5.3%. from a level of 1.8 to 3.4 million tons. The major maize-producing regions are Southern, Western. and Central Mindanao. the Cagayan Valley. and Central Visayas, which accounted for 69.4% of total maize production in 1984-85 and included 71% of the total maize area in the country. The amount of land planted to maize increased annually at a rate of 2.9%. from 2.3 million hectares in 1972-73 to 3.3 million hectares in 1984-85 (Table 1).

Table 1. Maize production, area, and yield in the Philippines, 1976-1985

Year	Production (t)	Area (ha)	Yield (t)
1976	2,717,320	3,193,160	.851
1977	2,774,770	3,242,520	.856
1978	2,796,085	3,158,070	.885
1979	3,090,255	3,252,430	.95
1980	3,122,790	3,201,070	.976
1981	3,109,685	3,238,690	.96
1982	3,290,175	3,360,700	.979
1983	3,125,885	3,157,480	.99
1984	3,346,235	3,270,210	1.023
1985	3,438,755	3,314,580	1.038
Average increase (%)	5.34	2.90	2.33

Source: Bureau of Agricultural Economics.

Both white and yellow maize varieties are grown. Of the total amount of maize produced in 1984-85, 64% was white and 36% was yellow. White maize production is declining, whereas that of yellow maize grew at an annual rate of 12% (Figure 1). Average yield per hectare improved modestly at an annual average rate of 2.3%. from 0.78 t/ha in 1972-73 to 1 t/ha in 1984-85. In 1984-85 Southern Mindanao recorded the highest maize yield (1.44 t/ha) and Central Visayas the lowest (0.44 t/ha).

The growth in maize production between 1972-73 and 1984-85 was caused by expansion in the area planted to the crop rather than by improvement in yield. However, in 1977 better yields contributed greatly to production growth because hybrids and improved open-pollinated varieties were introduced. This increase was seen only in yellow maize, since the hybrids and varieties introduced in 1977 were of that type. Improved varieties of white maize were introduced in the early 1980s.

In spite of the significant increase in total production during the past 10 years, the Philippines has not met the increasing demand for maize and has depended on imported grain to fill the deficit. Maize research and development efforts are basically aimed at making the country self-sufficient. It is hoped that this can be done through yield improvement and by making maize production a more profitable venture for farmers.

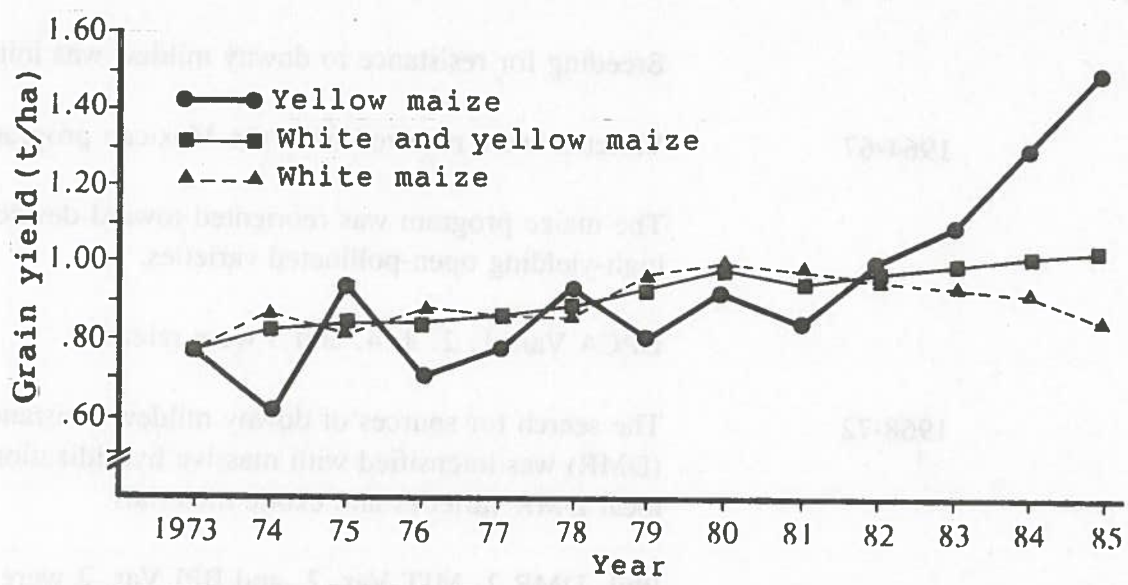


Figure 1. National trends in maize yield by maize grain color, The Philippines, 1972-73 to 1984-85

Varietal Improvement

Background--Maize varietal improvement in the Philippines began with the founding of the University of the Philippines College of Agriculture (UPCA) at Los Baños 77 years ago. Until the mid-1960s, all maize improvement work was done at UPCA. A brief review of the varietal improvement activities since 1945 is presented below (Lantin et al. 1983).

Year	Activity
1945-51	Production and testing of crosses between local varieties was started; extraction of inbred lines was begun in 1949.
1952-63	Varietal improvement became a cooperative effort with the Bureau of Plant Industry, Bureau of Agricultural Extension, and agricultural schools.
	The first double-cross hybrids were developed and released.
	Lines with T-type male sterile cytoplasm were found to be susceptible to leaf blight.
	Breeding for resistance to downy mildew was initiated.
1964-67	Varieties were received from the Mexican program.
	The maize program was reoriented toward developing high-yielding open-pollinated varieties.
	UPCA Vars 1, 2, 3, 4, and 5 were released.
1968-72	The search for sources of downy mildew resistance (DMR) was intensified with massive hybridization of local DMR varieties and exotic materials.
	Phil. DMR 2, MIT Var. 2, and BPI Var. 2 were released.
	Improvement of Tiniguib was begun at Mindanao Institute of Technology (MIT).

1973-79 The composite breeding approach was adopted.

Population development and improvement were started through full-sib selection of DMR composites.

In addition to breeding for downy mildew resistance, work on insect resistance, improved protein quality, and screening for adaptation to cropping pattern was initiated. Inbred line extraction and hybrid development were resumed.

Participation in CIMMYT's international variety/progeny trials was started.

Research and development of hybrid seed were initiated by the private sector.

Phil. DMR Comp. 1 and 2, Super Sweet Comp. 1, Yellow H.E. Opaque (Protena), and Glutinous Comp. released.

1980-present A comprehensive maize breeding program was formulated.

Breeding/screening work for resistance to corn borer and diseases other than downy mildew was intensified.

Varietal screening for resistance to drought and acid soils was initiated.

Increased emphasis was given to population development and improvement; other methods were adopted for population improvement.

Inbred lines were developed and tested on a large scale.

A number of hybrid cultivars were released and marketed by private seed companies.

Participation of other institutions/agencies in maize varietal improvement work increased.

CIMMYT's international variety trials were received by other cooperating institutions.

IPB Var. 1 and IPB Var. 2 released by the Institute of Plant Breeding (IPB), University of the Philippines at Los Baños (UPLB).

At present five public institutions are actively engaged in maize varietal improvement work: the Institute of Plant Breeding at UPLB, University of Southern Mindanao (USM), Central Mindanao University (CMU), the Bureau of Plant Industry (BPI), and Visayas State College of Agriculture (VISCA). Three private seed companies conduct hybrid seed research and development in the Philippines: Pioneer Overseas Corporation, the San Miguel Corporation, and Cargill Seeds, Inc.

Breeding objectives and systems--The major objectives of maize breeding programs in the Philippines are:

* High and stable yield under a wide range of growing conditions
* Resistance to diseases (downy mildew, caused by Peronsclerospora philippinensis Weston, and stalk rot, caused by Erwinia carotovora var. chrysanthemi) and to corn borer (Ostrinia furnacalis Guenee)
* Early maturity (harvest 85-100 days after emergence) and short to medium plant stature
* Resistance/tolerance to stress environments (drought and acid soils)
* High grit recovery and good eating quality in white maize

These are by no means the only characteristics that the maize breeder considers when conducting selection. Such traits as uniformity in plant type, lodging resistance, and husk cover are also important.

In the Philippines a great majority of maize growers are small-scale farmers, and the facility with which seed is produced and distributed is a major factor determining which maize cultivars to develop. Much of the resources devoted to maize breeding by public institutions are therefore directed toward developing open-pollinated varieties in the form of composites or synthetics. The IPB breeding program at UPLB, however, maintains an inbred line development and hybrid breeding component.

Developing breeding populations is the first phase of a comprehensive program. Populations are developed out of adapted materials and new germplasm acquired periodically from various sources, including CIMMYT. Selected parental materials can make equal or unequal contributions to the resulting composites.

The composites undergo intrapopulation improvement via recurrent selection. Initially, mass selection is employed to improve highly heritable and easily observable traits. After two or three cycles of mass selection, yield improvement begins using family selection: half-sib selection (modified ear-to-row) and S_1 progeny selection. At UPLB, two populations are being improved via S_1 progeny selection, and four are undergoing modified ear-to-row selection.

The improved versions of the populations are used as source populations for developing cultivars. The two commercial varieties, IPB Var. 1 (yellow seeded) and IPB Var. 2 (white seeded) were derived from these populations. The bulked seed of selected families from the latest cycles of selection constitute the breeder's seed of these varieties.

The derived populations are also major sources of inbred lines. Line extraction is basically done through the pedigree method, and tests of combining ability start in the S_3 generation. The IPB program has developed and tested a number of lines that are now being used to produce synthetic varieties and hybrids (three-way and double crosses).

CIMMYT's international progeny variety trials are also major sources of potential varieties. The Philippines participates in three types of trials, namely, International Progeny Testing Trials (IPTTs), Experimental Variety Trials (EVTs), and Elite Variety Trials (ELVTs). Cooperators in these trials include five public institutions and a private seed company. Formation of some experimental varieties has been requested from CIMMYT based on the results of several IPTTs. Also, some selected entries from the EVTs and ELVTs are undergoing regional tests in the country.

Variety testing and release--Before a variety is released for commercial grain production, it must have undergone and passed a series of agronomic performance tests. The last of these is the multilocation National Cooperative Test (NCT) conducted for at least two seasons in experiment stations of the Bureau of Plant Industry and various agricultural universities. The results of these tests are the primary basis upon which the Philippine Seed Board recommends varieties. This interagency/institutional body determines varietal releases for all crops in the Philippines. On-farm data, if available, are considered to complement data from the experiment station.

A summary of yield data of nine entries in the NCTs conducted during the 1985-86 dry season is shown in Table 2. The first four entries are hybrids, and the rest are open-pollinated varieties. Across locations the hybrids were superior to the composites in grain yield, though in some locations some of the composites performed at least as well as the hybrids. Most of the test entries showed a definite yield advantage over the farmers' variety.

In addition to the regular trials, during the last two years varieties have been grown using few production inputs. This type of test was characterized by low fertilizer levels (25% of the N level of the regular trial), no pesticide application for controlling corn borer, and a lower population density (53,000 plants/ha compared with 66,000 plants/ha for the regular trial). The accumulated data did not support the apparently widely held belief that most hybrids tested maintained their superiority over the open-pollinated varieties even at low production input levels. However, their yield advantage was higher at high input levels. The open-pollinated varieties, on the other hand, showed relatively more stable agronomic performance across different environments than did the hybrids.

Table 2. Performance of maize cultivars at various locations in the Philippines, 1985-86 dry season

	Mean yield (t/ha)[a]							
Entries	Ilagan	UPLB	Pili	La Granja	Tupi	USM	CMU	Mean
Hybrids:								
P3228	10.2	5.6	4.3	5.9	6.7	6.4	6.6	6.5
P3274	9.8	5.9	5.1	5.7	7.0	6.9	6.5	6.7
SMC309	9.4	4.8	4.7	5.9	4.8	5.9	6.4	6.0
CS711	10.8	5.3	4.8	5.8	6.2	6.7	5.2	6.4
IPB Var 1	9.0	4.5	4.0	4.5	4.3	4.4	4.5	5.0
IPB Var 2	7.6	4.8	4.4	4.0	5.3	4.9	4.4	5.1
IPB Var 4	8.3	4.8	3.6	4.1	4.5	4.6	5.2	5.0
SMARC1283	8.8	4.7	4.2	5.4	3.7	5.1	4.5	5.2
Farmers' var.	5.1	4.1	3.6	3.1	4.5	4.0	4.8	4.2
LSD (.05)	1.1	0.8	1.0	0.8	1.1	0.8	0.9	

[a]UPLB = University of the Philippines at Los Banos, USM = University of Southern Mindanao, and CMU = Central Mindanao University.

Maize varieties/hybrids released for commercial production during the last 10 years are listed in Table 3. Not one of these varieties/hybrids has occupied more than 20% of the total area devoted to maize in the country. It is estimated that the largest portion of the area is still planted to the traditional white variety, Tiniguib, and its derivatives.

Agronomy and Crop Protection

Agronomic research conducted in experiment stations has dealt with tillage systems, planting patterns, population density, fertilizer application, and soil and water management. A significant number of studies have also been done on maize cropping systems.

One of the most extensive studies conducted during the last 15 years was on fertilization. The main objective was to develop a fertilizer recommendation for all soil types on which maize is grown. Field experiments conducted in the early 1970s at 722 sites covering 354 soil types revealed that 33% of the soil types required N, P, and K, 42% needed NP, 22% required N only, and 3% needed a combination of N, K, P, and PK. Recent studies, however, provided more useful data that can aid in interpreting yield responses and predicting nutrient needs. Results of 48 field experiments showed that soils responding to nitrogen fertilization had organic matter contents ranging from 0.7 to 5.0%. In soils responding to phosphate fertilization,

Table 3. Maize varieties/hybrids released in the Philippines, 1975-85

Variety/Hybrid	Year released	Type of cultivar[a]	Seed color and endosperm texture
Phil. DMR Comp. 1	1975	OP	Yellow-flint
Phil. DMR Comp. 2	1975	OP	White-flint
IPB Var. 1	1981	OP	Yellow-flint
P 6181	1981	H	Yellow-flint
Hycorn 9	1981	H	Yellow-flint
SMC 102	1982	H	White-flint
SMC 153	1983	H	Yellow-flint
CS 711	1983	H	Yellow-flint
SMC 305	1984	H	Yellow-flint
IPB Var. 2	1984	OP	White-flint
P3228	1985	H	Yellow-flint
SMC 309	1985	H	Yellow-flint
P 3224	1985	H	White-flint
P 3274	1985	H	Yellow-flint

a OP = open-pollinated variety and H = hybrid.

soil test values ranged from 3 to 40 ppm. Soils responsive to potassium fertilization had 0.23 to 588 ppm (Lantin et al. 1983).

Crop protection research has focused on a number of diseases and an insect pest. For many years the development of varieties resistant to downy mildew, caused by P. philippinensis, has been the center of maize breeding efforts. An extensive search for a chemical control for this disease accompanied the breeding work. Such efforts produced research breakthroughs that substantially reduced incidence of downy mildew in the field. A number of resistant varieties are now available, as well as a fungicide (metalaxil (Ridomil/Apron 35SD) that provides adequate protection when it is used as a seed dressing.

Granular and sprayable insecticides that are effective against corn borer may be obtained, but they are expensive and sometimes do not provide adequate control. Furthermore, populations of natural enemies/predators are adversely affected by insecticide application, and there is little opportunity for biological control.

In recent research a way has been found of enabling farmers to control the corn borer with minimum use of insecticide. It has been found that detasseling. if done at the proper time, substantially reduces infestation. This means of control was based on the usual observation that most of the second-brood third and fourth instar larvae of the insect use the tassel as their shelter and source of nourishment before boring into the stalk. Detasseling can substitute for one or two applications of insecticide. It is now recommended technology for the control of corn borer, particularly on small farms.

On-Farm Research

Research results and technologies developed on experiment stations need to be tested under conditions on farmers' fields. A farmer will adopt a new technology if and only if it proves to be better than current farming practices and to result in higher income.

On-farm research (OFR) on maize is currently undertaken by the University of Southern Mindanao (USM) and the Ministry of Agriculture and Food (MAF). The OFR program at USM, conducted in cooperation with CIMMYT and IPB, is primarily intended to try out OFR procedures on a pilot basis to ascertain their role in university activities and to develop useful technologies for farmers in a defined area. Activities include diagnosis of farmers' circumstances, problems, and practices through a review of secondary data; exploratory and formal farm surveys; and field observations.

The study area is the municipality of Bagumbayan, a major maize-producing area in Sultan Kudarat Province on Mindanao, where almost all the maize planted is a white flint type. The researchers indentified three major problems: weed competition, nitrogen deficiency, and use of a native variety (Tiniguib) with low yield potential. On-farm experiments included fertilizer trials, weed control trials, variety trials, and fertilizer x variety trials. Highlights of the results are given below.

1. Using the new white variety IPB Var. 2, it was found that 60 to 69 kg N/ha was the most profitable fertilizer rate for most tenants and owner-operators.

2. A comparison of three production technology levels showed the hybrid P6181 package of technology slightly outyielding the OFR package using IPB Var. 2. Economic analysis, however, pointed out that the OFR package is more profitable than the hybrid package of technology and the farmers' practice.

3. Results of weed control experiments showed that low to medium doses of herbicides can be more efficient and more economical than the farmers' weed control practice.

4. Results of variety trials conducted at three locations in the study area revealed that all improved varieties were generally more profitable to use than the farmers' variety, Tiniguib. It was felt, however, that further tests should be conducted.

The technology verification program of the Ministry of Agriculture and Food is designed to develop location-specific and cost-effective technologies for small-scale farmers. The program engages in two major research activities: on-farm testing of cropping patterns and testing of component technologies used in the cropping patterns.

The program is carried out through the Regional Integrated Agricultural Research System (RIARS) in each region. The RIARS, as its name indicates, is the regional program for agricultural research, and integrates all activities in crops, soils, livestock, extension, and socioeconomics. It is run by a RIARS Manager with a core staff from five disciplines representing the fields just mentioned.

Farm trials, replicated four times across farmers' fields, are conducted in outreach sites by the Provincial Technology Verification Teams. The choice of research sites and farmer-cooperators is guided by baseline survey data indicating that they appear to be representative of the community.

Results of on-farm trials for 1984-85 showed that maize is the dominant crop in production systems in only a few of the country's 76 provinces. In regions where maize is dominant, the cropping pattern that is usually practiced is two crops of maize or a crop of maize followed by another crop, usually peanut or mungbean. Results of the cropping pattern trials, however, showed that some modifications in the cropping pattern (adding another crop, for example) generally improved yield and economic returns from the land.

Seed Production Program

The impact of a new variety in a country's crop production program can only be realized if there is an adequate seed production and distribution system. Good quality seed of a new variety should be made available to the farmers as soon as it is released by the breeding institution.

In the Philippines, the seed production and distribution scheme for open-pollinated maize involves three sectors: the breeding institutions, the Bureau of Plant Industry (BPI), and private seed growers. Breeder's and foundation seed are produced and maintained by the breeding institutions. The BPI is given foundation seed that is distributed to its seed farms acorss the country. Registered seed produced from these farms is sold to certified seed growers. These growers, however, are few, and most have small farms with inadequate seed processing and storage facilities. Only recently have some private hybrid seed companies expressed interest in producing seed of varieties developed by public institutions. One of these companies is now directly involved in producing and marketing a yellow composite released by IPB. Hybrid seed produced by seed companies has the benefit of a good and wide distribution/marketing network.

Maize Production Programs

Since 1972 the government has launched several production programs with the following goals:

* Eliminate imports and generate surplus for export
* Support the expanding livestock industry
* Increase farmers' income

The programs were basically designed to increase productivity by promoting a set package of technology in selected maize production areas. The package of technology includes recommended varieties that have been approved by the Philippine Seed Board, with accompanying general application rates for fertilizer and chemicals explained in simplified steps for ease of dissemination to farmers.

1972-74: The White Corn and Feedgrains Program--This program covered white and yellow maize, sorghum, and soybean. Based on the recommended package of technology for maize, the program set a target yield of 2 t/ha, determined the loan budget, and contained other components such as training, marketing, and program management. Although self-sufficiency in maize was not achieved, the increase in productivity in the selected maize areas led to a bumper crop that helped alleviate the problem of rice shortages and made possible the rationing of a rice and maize mix. The program yields were 0.92 t/ha for yellow maize and 1.34 t/ha for white, whereas the national average yield was 0.84 t/ha.

1974-77: The Masaganang Maisan Program (Bountiful Corn Production Program)--The componenets of this program, patterned after the Masagana 99 Rice Production Program, were the package of technology, noncollateral credit, maize procurement at the support price, and technology extension. Along with efforts to increase productivity, the downy mildew-resistant varieties were distributed through the seed kit system and planted on some 460,950 ha. The program yields increased to 1.5 t/ha and the national average yield rose to 0.98 t/ha.

1977-82: The Maisan Program--With the introduction of yellow hybrid maize in the market, the program strategies were changed. Three levels of technology were designed:

Maisan 22 (50 kg) low-level technology
For the marginal, hilly areas, the white maize/ipil-ipil (Leucaena leucocephala) cropping system was recommended. Demonstration farms were established in the areas.

Maisan 77 (50 kg) medium-level technology
The open-pollinated varieties, particularly the IPB varieties, were recommended in areas where farmers can shift to yellow maize.

Maisan 99 (50 kg) high-level technology
With this technology package, hybrids were promoted in suitable areas as well as where demonstration farms and farmer training had been done. In the selected project sites, the target areas were reduced

and a separate corps of technicians was assigned. It was during this program period that the crop insurance system was implemented to reduce risk for lenders and borrowers. Crop insurance covered damages against natural calamities and major pests and diseases.

At the start of the program, it was expected that more farmers would adopt the open-pollinated varieties rather than hybrids. However, the program was beset with problems in seed production and distribution of quality seed. Maize output dropped as a result of severe drought in 1982-83, followed by a heavy infestation of corn borer. This prompted the government to import the largest volume of maize ever, about 406,000 t. With the tight economic situation in 1984, the program suffered from the credit squeeze, spiralling production costs, and delayed fertilizer imports.

July 1984 to present: The Expanded Corn Program--During the first season, only yellow hybrid maize was covered by this program. With the impending rice shortage, white maize was included. The same packages of technology were adopted in this new program as had been used before. The major change was the credit delivery system for small-scale farmers. In addition to the banking institutions, nontraditional lending conduits were tapped, such as government agencies, trader-millers, and maize end-users.

In anticipation of large harvests, the postharvest facility assistance program was implemented. Dryers and shellers were made available in key production sites, and loans were extended to private corporations for large-capacity processing facilities. But despite these efforts, the goals have not yet been achieved.

The technology adoption rate has been very slow. Since the introduction of hybrids and improved varieties in 1977, growth in production has been attributed more to yield improvements than to expansion in maize area. Nevertheless, there is still great potential to increase production by accelerating the adoption rate. Structural policy measures and program strategies can definitely influence growth in productivity. Several studies have strongly indicated that the Philippines has a comparative advantage in maize production. There is still a huge local market that can be satisfied by local production.

There is great potential for the country to become self-sufficent in maize production and generate surplus for export to Japan and Taiwan, countries that are both net maize importers. However, clear policy measures need to be initiated by the new government in support of the basic aim of accelerating productivity to improve farmers' incomes.

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Discussion

R.N. Wedderburn: You show that white maize yields are decreasing whereas yellow maize yields are increasing. Could one reason for this be that in the Masaganang Program. loans for inputs are given only for hybrids. and only recently for improved varieties, and that few white maize varieties qualified for input loans?

G. Minguez: Loans for white maize varieties were suspended for one season only. July to December 1984. The farmers have been using old seed of white maize varieties. and the quality has deteriorated over the past ten years. It has only been since 1980-81 that improved varieties of white maize and white maize hybrids were introduced in the market. To date. IPB Var. 2 (white maize) is not available in commercial volumes. Very few farmers have adopted hybrid white maize because of the high cost. Farmers who plant white maize are mostly maize consumers in marginal areas who plant the crop for subsistence. Furthermore. white hybrid maize yields less than yellow hybrid maize. Although there is a financing program for white maize. very few lenders extend loans because of the low collection rate. We hope that with the better open-pollinated IPB Var. 2 lending institutions will find it attractive to make loans for its production.

C. Chutkaew: How did the Masaganang Maisan 99 Program relate to your breeding program. and did yield per hectare increase?

G. Minguez: The package of technology recommended in the Masaganang Maisan Program was based on the results of the breeding program. New varieties passing through the National Cooperative Trials and the Philippines Seed Board are used in the program. Currently, for example, support program strategies are designed for the DMR and the IPB varieties. Program yields of IPB Var. 1 average about 2.66 t/ha. The program contribution to total production is about 20%. National average yields increased from 0.85 to 0.98 t/ha between 1977 and 1981.

K. Khan: Does such a small number of variety, fertilizer, and verification trials serve the purpose of developing recommendations in your area?

G. Minguez: No, we actually have several cycles (two or three), and then the verification trials are conducted prior to recommendation.

C. De Leon: What is the background of your SMARC 2, SMARC 4, and SMARC 6?

G. Minguez: SMARC 2 is Santa Rosa 8073; SMARC 4 is Ikenne; and SMARC 6 is Gandajika.

D. Winkelmann: Is corn borer the principal problem in each of the major maize-producing areas?

G. Minguez: It is not the principal problem, but it is certainly an important problem in most of the maize-growing areas in the Philippines, particularly in the wet season. When a farmer is unable to plant early, the crop is very likely to be heavily infested by corn borer. In some areas yield losses from this pest are as high as 80%.

P. Sumarto: Would you kindly explain the source of stem borer infestation in your trials; is it natural or artificial?

G. Minguez: We practice artificial infestation in corn borer resistance screening, for which egg masses are produced in the laboratory. However, at certain times of the year, as in the wet season, natural populations of the insect can be very high, so artificial infestation may not be necessary. We plant late if we have to rely on natural infestation.

P. Pancharanan: Once you have identified the problems affecting maize yields. how do you plan to conduct your future work to increase the benefit of maize production at the farmers' level?

G. Minguez: The results of the diagnosis serve as the basis for our on-farm trials. Note that our on-farm experiments focus on solving the problem identified. The hypothesized causes for production problems give us insight into the treatments we will use. The results of the diagnosis actually help us set our priorities in on-farm research.

J. Singh: What has been your experience with Ridomil/Apron to control downy mildew?

G. Minguez: Ridomil/Apron 35 8D has provided good protection against downy mildew. It is used by two seed companies as a seed dressing for their hybrids. So far. there is no documented report that the downy mildew pathogen has become resistant to this fungicide.

Thailand

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Quite interesting changes took place in the planted area. production. and export value of maize in Thailand from 1975 to 1984 (Table 1). If we divide this time span into two five-year periods, a marked increase in area planted (22%). total production (14%). export quantity (34%), and export value (55%) becomes apparent. However. the average yield and farm prices were not satisfactory, the former rising only 9% and the latter 1%.

The Department of Agriculture. in an effort to increase yield per hectare. introduced the open-pollinated variety Guatemala (Tequisate Golden Yellow Flint) in 1951. The maize breeders of the Department multiplied Guatemala, improved its yield potential. and distributed the cultivar to farmers as Phra Phutthabat (PB). This variety was used extensively until 1972. but because of its susceptibility to downy mildew disease it was replaced by Thai DMR 6 in 1973 and Suwan 1 in 1976 (Chutkaew 1982).

As a result of collaborative research between the Department of Agriculture and the Rockefeller Foundation. the Corn Breeding Project of Kasetsart University was able to release Suwan 1. Two maize hybrids. Kasetsart Single Cross 2301 (KSX 2301) and Kasetsart Three-Way Cross 2602 (KTX 2602) were recommended by Kasetsart University in 1982 and 1985. respectively (Chutkaew et al. 1985). Two synthetic varieties. Kasetsart Synthetic 4 (KS 4) and KS 6, were released in 1985 (Chutkaew et al. 1986). In 1982 the Department of Agriculture recommended a young ear or "baby corn" variety named Rangsit 1 (Chutkaew et al. 1983). Research on quality protein and high-oil maize has been conducted since 1969.

Table 1. Maize production and exports in Thailand, 1975-84

Year	Planted area (000 ha)	Average yield (kg/ha)	Total production (000 t)	Exports: Quantity (000 t)	Exports: Value (US million dollars)
1975	1312	2375	2863	2072	281
1976	1285	2388	2675	2388	280
1977	1205	1719	1677	1518	164
1978	1386	2125	2791	1955	212
1979	1525	2013	2863	1988	278
1980	1434	2225	2998	2175	360
1981	1567	2356	3449	2547	358
1982	1679	2300	3002	2801	358
1983	1688	2269	3552	2630	365
1984	1817	2431	4226	3116	437

Source: Agricultural Statistics of Thailand, crop year 1979/80-1984/85, Ministry of Agriculture and Cooperatives.

Breeding Systems

Several breeding systems are employed in the development of varieties in Thailand. Controlled mass selection was used with Guatemala from 1961 to 1975, and the cultivar was released as Phra Phutthabat (PB), PB 1 to PB 12 (Chutkaew 1982).

The backcross method was applied with Suwan 1 to develop downy mildew resistance. Two resistance sources, Philippine DMR 1 and Philippine DMR 5, were crossed to Thai Composite 1 (Suwan 1 cycle 0). Resistance to the disease was successfully incorporated after three backcrosses had been made to the advanced cycles of improved Thai Composite 1.

S_1 family recurrent selection has been applied with Suwan 1, a maize composite, from cycles 0 to 10. Suwan 1 has been recommended to maize growers in Thailand since 1975. This same method is also practiced with Suwan 2, a short-season maize variety, among others.

Variety and composite crosses are used to form new varieties. Young ear or baby corn, Rangsit 1, was developed from three elite varieties, UPCA Var. 1, Cupurico Flint Compuesto DMR(F)C2, and D 745. Rangsit 1 has been recommended to farmers since 1982 by the Department of Agriculture (Chutkaew et al. 1983)

In work on hybrids, a number of inbred lines were extracted from Suwan l(S)C4 and from diallel crosses. Some promising lines are Kasetsart inbred 3(Ki 3), Ki 11, and Ki 17. Ki 20 was extracted from Caripeño (S)Cl. Kasetsart Single Cross 2301 (KSX 2301) has been made from Ki 3 and Ki 11. Kasetsart Three-Way Cross 2602 (KTX 2602) has been developed from KSX 2301 and Ki 20 (Chutkaew 1985a and Chutkaew et al. 1985b). Inbred lines Ki 21 and Ki 22 were extracted from the commercial hybrids Pacific 9 and Pacific 11 x Suwan l(S)C6, respectively. Both Ki 21 and Ki 22 were crossed to KSX 2301 and showed good yield and agronomic characters.

The Corn Breeding Project at Kasetsart University has developed three synthetic maize varieties, namely Kasetsart Synthetic 4 (KS 4), KS 5 and KS 6 (Chutkaew et al 1986). In developing KS 4 and KS 6, S_1 lines were used. KS 5 was formed from six promising populations by using full-sib families from different genetic backgrounds. Both KS 4 and KS 6 have been considered for release this year (Chutkaew et al. 1986a, 1986b).

Other breeding systems that have been used include:

* Half-sib family selection
* Line improvement
* Topcross using the latest cycle of Suwan 1 as tester
* Testcross using the promising inbred lines or hybrids as testers

Variety Testing
Promising materials are sent for testing both at experiment stations and in farmers fields in maize-growing areas. Testing is conducted at a greater number of locations for elite varieties, composites, synthetics, or hybrids. To obtain more reliable information, data will be collected over years, seasons, and locations.

Progress in Maize Improvement
Suwan 1(S) cycles 0 to 9 were tested over two years in the 1983 late season and 1985 early rainy seasons at Farm Suwan; results are given in Table 2 (Chutkaew et al. 1984, 1986). The mean grain yield of every cycle increased sharply over that obtained in cycle 0. However, the yield gain in the later cycles (7, 8, and 9) seems small. The agronomic characters were improved over those of cycle 0.

Table 2. Mean grain yield and ear height of Suwan 1 (S), Farm Suwan, 1983 late (L) and 1985 early (E) rainy seasons

Cycle	Grain yield (kg/ha) 1983L	1985E	Average	Ear height (cm) 1983L	1985E	Average
C0	3779	8000	5890	118	135	127
C1	4524	8524	6524	110	135	123
C2	4819	8453	6636	113	141	127
C3	5157	8282	6720	109	134	122
C4	5627	8222	6925	113	130	122
C5	5839	9137	7488	111	134	123
C6	6260	9066	7663	115	141	128
C7	6313	9583	7948	116	134	125
C8	6475	9409	7942	117	130	124
C9	6865	9416	8141	116	130	123
Mean	5566	8809	7188	114	134	124

The hybrids KTX 2602 and KSX 2301 were tested in regional yield trials with other hybrids and varieties and compared with Suwan 1(S)C8 as a check variety (Table 3). Those two hybrids yielded 6188 (13%) and 5650 kg/ha (3%) higher than Suwan 1. The hybrids were also better than the check in most agronomic characters (Chutkaew 1985a, 1985b, 1986b).

Kasetsart synthetics KS 4, KS 5, and KS 6 were included in regional yield trials with other varieties as well as hybrids, with Suwan 1(S)C8 as a check variety (Table 4). Varieties KS4 and KS6 yielded 7321 (6%) and 7056 kg/ha, respectively, 6 and 2% more than Suwan 1, whereas KS 5 yielded 1% less than Suwan 1. All of the synthetic varieties had greater plant and ear height, but with respect to lodging, they seemed similar to Suwan 1. There were no differences in other agronomic characters between the synthetics and check variety (Chutkaew et al. 1986a, 1986b).

Future Research and Development

In the future we hope to give more attention to conventional methods of breeding. The biotechnological approach will also receive attention. Since maize production has been affected by aflatoxin and other environmental problems in recent years, it might also be worthwhile to explore the possibilities of tissue culture/protoplast fusion. However, given the limited resources available at present, we may have to wait some time before we can begin taking advantage of these new technologies.

Table 3. Mean grain yield of maize hybrids tested at various locations in Thailand, 1983-85

Pedigree	Yield (kg/ha) at 15% moisture KU[a]	KU[b]	KU[c]	KU[d]	DA[e]	Mean	Percent yield difference	Average ear ht. (cm)
KTX 2602	8056	5063	5025	6088	6400	6188	113	109
KSX 2301	6869	3831	4825	5513	6081	5650	103	90
Check: Suwan 1(S)C_8	7363	4394	4125	5281	6069	5488	100	114

[a] Average from 6 trials, Kasetsart University (KU) Corn Breeding Project, 1984-86.

[b] Average from 1 trial, KU Corn Project No.3, 1985.

[c] Average from 9 locations at Agricultural College, KU On-Farm Trial Project, 1984-85.

[d] Average from 15 locations in farmers' fields, KU On-Farm Trial Project, 1984-86.

[e] Average from 9 locations, Department of Agriculture.

Cooperation with Other Institutions

To improve our research, development, teaching, and activities, we exchange information, knowledge, technologies, and selected plant materials with other institutes. Besides CIMMYT we cooperate with a number of other organizations in both the public and private sectors, including the following private seed companies: Charoen Phokaphan, Pioneer, Cargill, Ciba Geigy, Pacific Seeds, Thai Seed Industry, Uni Seeds, and San Miguel.

On-Farm Research

The National Corn and Sorghum Research Center was established in 1969. Six years later Kasetsart University's outreach program was initiated to demonstrate recommended technology packages in farmers' fields. The Center's main objectives are to improve plant varieties, to determine which cultural practices are most suitable, and to study the economic aspects of maize and sorghum production. As the production packages are tentatively developed, the Center's policy is to introduce them to farmers, so that they can be compared with farmers' own practices in terms of costs and benefits.

Table 4. Performance of maize tested at 14 locations, 1984-85

Pedigree	Grain yield (kg/ha) KU[a]	KU[b]	KU[c]	DA[d]	Mean	Average ear ht. (cm)
KS 4(S)C1-F_1	8266	10,300	7142	6563	7321	134
KS 5(S)C0-F_3	--	9944	6842	6080	6783	143
KS 6(S)C1-F_1	8053	9794	6743	6485	7056	135
Check: SW 1(S)C8-F_3	7979	9513	6571	6300	6886	124

[a] Average from two trials conducted in 1984, Kasetsart University (KU) Corn Breeding Project.

[b] Results from one trial conducted in 1985, Kasetsart University (KU) Corn Breeding Project.

[c] Average from six locations (farmers' fields), KU On-Farm Trial Project.

[d] Average from five locations, Department of Agriculture.

Maize area--The area planted to maize in Thailand increased from 1.3 million hectares in 1976 to 2 million in 1985, whereas yield increased only from 2.34 to 2.35 t/ha during the same period. The main regions where maize is cultivated are located mostly on the central plain and in some provinces of the northeast (Figure 1). The main soil groups where maize is planted are (1) reddish brown lateritics (Paleustults and Haplustalfs) and (2) black soil types (Eutropepts, Calciustolls, and Argiustolls). The rainfall distribution is bimodal, with the early rains starting in mid-Aapril and the main rainy season beginning in mid-May. More than 60% of farmers plant their maize in the early season and produce other field crops such as sorghum, mungbean, and groundnut as the second crop.

Relationship between experiment station research, on-farm research, extension, and farmers--The pathway by which technology is transfered to farmers, as established by the National Corn and Sorghum Research Center, starts with

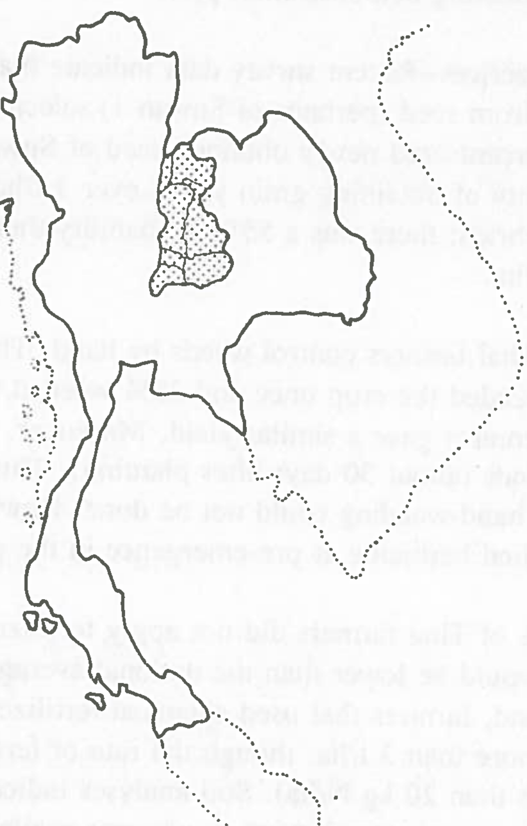

Figure 1. Maize-growing regions of Thailand (the shaded areas are provinces in which over 100,000 ha are planted).

cooperative work involving on-station research and on-farm experimentation. Results from on-farm research are applied in verification trials comparing different levels of new production technologies with the farmer's practices in terms of costs and benefits. These trials are conducted by researchers, extension workers, and farmers. It is expected that farmers will adopt the package that is least costly to implement and from which the maximum benefits can be obtained.

There are four steps in transferring technologies to farmers.

1. Summarizing research data from the experiment station and analyzing farmers' practices through surveys

2. Conducting on-farm research at different levels of management

3. Verifying production input implications and economic returns

4. Conducting demonstration plots

Farmers' practices--Recent survey data indicate that about 22% of Thai farmers grow maize from seed (perhaps of Suwan 1) selected from the preceding season. Fifty-nine percent used newly obtained seed of Suwan 1, and 19% used hybrids. The probability of obtaining grain yields over 3 t/ha was 41% with Suwan 1 and 71% with hybrids; there was a 55% probability that the farmers' variety would yield less than 2 t/ha.

In general, Thai farmers control weeds by hand. The survey data revealed that 57% of farmers weeded the crop once and 35% weeded twice. The two methods of mechanical control gave a similar yield. Moreover, 7% of farmers applied paraquat post-emergence (about 30 days after planting). This method was found to be necessary if hand-weeding could not be done. However, fewer than 1% of the farmers applied herbicide at pre-emergence in the previous season.

Around 50% of Thai farmers did not apply fertilizer, in which case the probability that yields would be lower than the national average of 2 t/ha was about 44%. On the other hand, farmers that used chemical fertilizer had a 55% probability of producing more than 3 t/ha, though the rate of fertilizer application was too low on average (less than 20 kg N/ha). Soil analyses indicated an excess of potassium content in the maize-growing areas, whereas available phosphorus varied from 3 to 67 ppm. Nitogen was found to be essential as a fertilizer supplement for maize.

Reports on a fertilizer experiment conducted over the past two years indicate that 16-20-0 fertilizer is more effective than 21-0-0 for maize and that the yield response to fertilizer rate depends on soil type. Fertilizer response was greater in reddish brown soils than in black soils.

The conventional land preparation practices of Thai farmers are first to burn the crop residues and then to plow once or twice. A tillage experiment on farmers' fields revealed that the average grain yield in the no-tillage system was not significantly different from yields obtained with conventional tillage practices. In addition, the response of maize to fertilization was found to be better under conventional tillage than under the no-tillage system. It seemed that plants utilized nutrients better under the former.

Summary of previous trials--Data on yield increases obtained over the past ten years through the use of production inputs are summarized in Table 5. The average yield increase was 13% for adopting improved open-pollinated varieties and 22% for hybrids. Herbicide treatment (atrazine applied preemergence) decreased yield by 1%, compared to hand-weeding by farmers. This was thought to be the result of the difference in soil moisture conservation between the two weeding methods. Hand-weeding by harrowing pulverizes the first few inches of topsoil, creating a self-mulching effect through which moisture loss through evaporation is reduced. Preventing further evaporation of subsoil moisture increases the supply of subsoil moisture during the dry period of the growing season.

Table 5. Increase in grain yield obtained from various production inputs, compared to farmers' practices, 1976-85

Input	Percentage gain
Variety	
Improved open-pollinated variety	13
Hybrid	22
Herbicide	-1
Chemical fertilizer	24
Variety x fertilizer	28
Variety x fertilizer x herbicide	35

Fertilizer application was found to be necessary for maize production during the entire 10 years of the study. Previous work had indicated that maize treated with chemical fertilizer yielded 24% more than untreated plots. The integrated input packages of variety, fertilizer, and herbicide increased yield by 35% over that obtained with the farmers' practices.

One important step in transferring new technologies to farmers is to verify whether the input package increases yield and then compare the costs with the benefits. Verification trials were conducted jointly by researchers, extension workers, and farmers, not only to demonstrate for farmers the new production technologies at different levels of inputs, but to increase the extension officers' awareness of the possibilities for transfer of maize production technology.

Grain yield increased with increasing input levels in every year of the experiment (Table 6). It seemed that the combination of recommended plant spacing plus herbicide and fertilizer application was more profitable with the improved variety (Suwan 1) than with hybrids (Suwan 2301). These results were similar to those of

Table 6. Treatments in on-farm verification trials

	Treatment					
	1	2	3	4	5	6
Variety[a]	F	R	R	R	H	H
Plant arrangement[b]	F	R	R	R	R	R
Weed control[c]	F	F	R	R	R	R
Fertilizer[d]	O	O	O	R	O	R
Yield differences (%):						
1983	100	102	109	121	--	131
1984	100	113	131	147	151	171
1985	100	107	114	138	115	137

[a] R = recommended variety Suwan 1, F = farmers' practice, and H = hybrid.

[b] R= 75 x 50 (2-3 plants/hill).

[c] F = hand-weeding and R = herbicide.

[d] R = applied and O = not applied.

the unfertilized treatment. Since the hybrid Suwan 2301 did not respond significantly to fertilizer application, a change of hybrid seed might be appropriate.

Using experimental results and information about farmers' practices, trials for on-farm research should be set up. Experiment sites should be representative of the maize-growing area, both in soil type and rainfall distribution. The levels of experiments should be:

1) Improved variety test

2) Commercial hybrid test

3) Weed control trial

4) Fertilizer experiment (type and rate)

5) Verification trial

6) Demonstration plots

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Discussion

J. Singh: What price premium can farmers expect if they grow high-oil maize? How much land in Thailand is likely to be planted to this kind of maize?

C. Chutkaew: We have not yet set up the correlation of increase and decrease in oil and yield against the price of high-oil maize. This is because we have not yet recommended any high-oil variety. However, there will be a good mutual agreement in price between farmers and the oil factory.

G. Minguez: What are the uses of maize and annual demand?

C. Chutkaew: In 1985, total production was approximately 5.03 million tons. Some 2.5 million tons were exported, and the remainder was for local consumption, mostly as animal feed.

M.M. Lantin: Under a given seed storage condition, do you observe a faster loss of seed viability in Suwan 1 than in other varieties?

C. Chutkaew: We have not found this to be a problem before. At our experiment station, Suwan 1 has no difference in seed viability when compared to other varieties.

M.M. Lantin: Please brief us on your experience with the seed exchange program.

C. Chutkaew: The Ministry of Agriculture and Cooperatives decided the target area. The Department of Agricultural Extension is in charge of the program. Agricultural Extension officers exchange seed of recommended varieties with farmers' seed, give advice, and follow up the program. So far, no problems have been found. Farmers are willing to accept and adopt seed of good varieties.

L.P. Oliva: In your verification trails. do you have the best-bet combinations as one of your treatments? If so, what was the basis?

R. Thurapom: Our results from 1983-85 indicated that treatment 4 (improved variety x plant arrangement x herbicide and fertilizer) was the best in terms of economics and agronomy, because hybrid Suwan 2301, when we used it. did not respond signfiicantly to fertilizer application.

L.P. Oliva: How many locations and cycles did you have in your variety x herbicide verification trials?

R. Thiraporn: Each year we conduct verification trials at about 20 locations.

M.Q. Chatha: In your herbicide studies over the last ten years. it was observed that herbicide application had a negative effect on yield. Do you still need to continue those trials?

R. Thiraporn: When the conventional weed control practice--hand weeding--was compared with the herbicide treatment. the average result was a negative effect on yield. but results from year to year differed. The results depended greatly on the length of the dry period when maize was at the vegetative stage. When the dry period was long. controlling weeds by hand was more effective than control by herbicide application at pre-emergence. because hand weeding by harrowing pulverizes the first few inches of topsoil and reduces further loss of subsoil moisture by evaporation. But when there was good rainfall during the first month after maize was planted. weed control by herbicide was more effective than hand weeding in terms of the time required to control the weeds, the labor necessary. and crop competition in the early stages of maize growth.

L.C. Kiang: With fertilizer. weed control, and hybrid seed. farmers' yields increased 37% in 1985. What was the increase in cost?

R. Thiraporn: The cost of fertilizer, herbicide. and hybrid seed increased. compared to farmers' practices. about 1800 baht/ha.

Vietnam

Do Huu Quoc, Institute of Agricultural Technology of South Vietnam, and Nguyen Van Chung, Maize Research Center

This paper reviews the present situtation of maize production and its long-term prospects in Vietnam.

The Importance of Maize Production in Vietnam

Maize ranks second to rice among Vietnam's cereal crops. It can be grown in any region of the country, from the highlands to the lowlands of the Red River and Mekong River Deltas. The cultivated area varies from 320,000 to 450,000 ha (5.7% of total cultivated area), with an average yield of 1.1-1.2 t/ha and production at 450,000-470,000 t/year (2.9% of total food crop production).

Most maize is cultivated in the traditional manner with very low levels of inputs. Local, low-yielding varieties are used, especially in the mountainous regions, which account for more than 40% of the total maize area. In those regions the average yield remains very low (0.8-0.9 t/ha).

Present Status of Maize Production

Since 1981 great attention has been paid to this crop, and a national development program has been established, which has been instrumental in bringing about important changes in maize production over the last few years. Between 1983 and 1985, area increased from 380,000 to 400,000 ha, yields from 1.1 to 1.5 t/ha, and production from 420,000 to 590,000 t. This rapid growth is due to:

- Extension of the maize crop in the Red River Delta provinces of the north and in transition regions of the south
- Release of new, improved high-yielding varieties
- Improved cultural practices

In the Red River Delta, maize is introduced in cropping systems of three crops per year as follows:

- Spring paddy (February-June), early summer paddy (June-September), and winter maize (September-January)
- Spring paddy, summer soybean, and winter maize

* Spring maize (February-June), full-season paddy (July-November), and legumes or vegetables (November-Janury)

In the transition and highland provinces of the south, maize is grown in rotation or mostly intercropped with soybean, peanut, and mungbean.

During recent years many improved composite varieties have been released for different ecological regions. For the north the early maturing varieties available are TSB2 (based on Suwan 2 from Thailand) and TSB49 (from Across 8049). The intermediate varieties are TH2A, HSB1, and TSB1 (based on Suwan 1 from Thailand), and late varieties include VM1 (based on population Tuxpeñito V524 from Mexico). For the southern part of the country, early maturing varieties are Improved Early Thai Composite, Nhaho Composite, and recently Pool 18 (tropical early yellow dent). The intermediate varieties are Western Yellow, TH2A, Tainan 11 Composite, and VM1.

The area planted to these varieties is growing rapidly. In the Red River Delta provinces, 80% of the area is planted to new varieties, and in the transition regions of the south the percentage is about 60%. But only 20% of the total area planted to maize is covered by improved varieties because a good seed production and distribution system does not exist. Intensive cultural techniques have been applied through extension programs at numerous cooperative farms where maize is produced. The government established policies to stimulate maize cultivation, has supplied fertilizers and pesticides, and offered a higher price for maize grain than for paddy.

Different research organizations have signed contracts for transferring new technologies to a large number of cooperatives. This includes extending new varieties or applying proper cultural practices.

As a result of these initiatives, the average yield and grain production in several provinces has doubled in the course of a few years. In the Hanoi suburban districts and Vinhphu and Thanh Hoa provinces, the average yield obtained on an area of 10,000 ha reached 3.0-3.5 t/ha and on 9,000 ha reached 4.5-5.0 t/ha. In the south the average yield of 50,000 ha cultivated in Dongnai province reach 2.0 t/ha in 1985.

In only a few years, cooperation between the Song Boi Maize Research Center and Institute of Agricultural Technology of South Vietnam and CIMMYT has given concrete results. A number of improved varieties developed using the materials and improvement methods of CIMMYT have been released, and many promising materials have been developed and are ready for release to producers.

Future Developments

Our tentative program for the next two five-year plans is to increase maize area to 600,000 ha by 1990 and reach 1 million ha by 1995. It is hoped that yields will rise to 2 t/ha in 1990 and 2.8 t/ha in 1995, with production increasing to 1.2 million tons in 1990 and 2.8 million in 1995. Clearly these are very high goals, and a number of problems in research, extension, and government policy must be solved before we can attain them. Our objectives are to:

* Enhance the research activities of two maize research centers, one in the north and another in the south, and develop new high-yielding composite varieties and proper cultural practices for hybrids to be developed in the future.

* Transfer technology to farmers' fields in the principal and most productive maize regions.

* Develop an efficient seed production and distribution system for the entire country.

It will also be important for the government to give priority to policies (particularly on prices of maize grain as well as fertilizers, pesticides, and other inputs) that could stimulate the development of maize production.

There are many difficulties to overcome before we can achieve our objectives, but we are confident that, through our efforts and active cooperation with CIMMYT, other international organizations, and various countries, they can be attained.

Discussion

R.P. Bosshart: What are the fertilizer recommendations for improved open-pollinated or hybrid maize varieties planted on upland (red) soils?

Do Huu Quoc: The fertilizer recommendations for improved open-pollinated maize varieties planted on upland (red) soils in South Vietnam are 80 kg N, 40 kg P_2O_5, and 40 kg K_2O for a yield of 4-5 t/ha. For the hybrid varieties, 120 kg N, 60 kg P_2O_5, and 60 kg K_2O are recommended for a yield of 5-6 t/ha.

Laos

Sounthone Sybounheuang and Sayamang Vongsak, Department of Agriculture, Ministry of Agriculture

In 1985 maize production in Laos reached 35,900 t, an 18% increase over that in 1976. The total maize area in 1985 amounted to 30,395 ha, or 4% more than in 1976. Improved varieties covered 30% of the total area planted to maize (Table 1).

Maize is second to rice as a staple crop in Laos and is produced throughout the country. Two kinds of maize are grown: sweet maize, grown to be eaten green, and regular maize, grown for animal feed. Hard maize is generally preferred to sweet maize for human consumption, but is also used for livestock and poultry feed because of its high starch content.

Breeding

In Laos the number of plant breeders is limited, and the level of farmers' education is quite low. Conventional hybrids have not yet been developed for several reasons:

* Breeders, equipment, laboratories, and money were lacking.
* There is no experiment station specifically for maize research.
* It is presently uneconomical to use hybrids because they are expensive and not available locally. The yield of F_2 seed is considerably below that of F seed.
* Hybrids are highly sensitive to the environment, most of them having been selected and tested under well-controlled conditions. As a result, they may not be suitable in farmers' traditional cropping systems.

Table 1. Maize production in Laos, 1976-85

	1976	1985
Total area (ha)	29,122	30,395
Average yield (t/ha)	1.04	1.18
Production (t)	30,387	35,900
Area covered by improved varieties	2,912	9,120
Average yield (t/ha), improved varieties	1.8	2.1
Production (t), improved varieties	5,240	19,150

Because of these difficulties during the past 10 years, the Maize Research Program was directed to produce synthetic varieties. The first synthetic introduced for general cultivation was HDK4, which can perform well in most areas of Laos. Under less intensive cultivation (poor management practices and few or no inputs), it still provides a profitable yield.

The Institution has conducted maize improvement at Haddokkeo Research Station, situated about 15 km south of Vientiane. The government's increased concern about maize improvement led to the establishment of the research center at Naphok in 1984, which is located in the northeast, 35 km from Vientiane.

Maize Improvement

Two kinds of improvement systems are presently used by the national program: modified ear-to-row half-sib selection and mass selection. The main objectives of selection are to improve the base varieties for yield, disease resistance, standability, and other characteristics necessary for commercial varieties in Laos.

Half-sib selection was done in late 1977 with a variety called Thai Composite 1. At harvest 100 of the best ears were retained from disease-free plants grown on a total area of 2500 m^2. Four cycles of selection had been completed by late 1979. The selected variety HDK3 has been produced and distributed to growers since early 1980.

Mass selection was initiated in 15 varieties from Hungary in early 1978 at Haddokkeo Research Station. These were mixed and planted in a block of 60 rows, 50 m long. Mild selection was practiced at harvest. A few downy mildew-resistant plants were eliminated in the field. All rotten ears and ears from extremely tall, short and lodged plants were discarded, though they might have been considered competetive. At harvest the 150 best ears were retained from disease-free plants grown over an area of 3000 m^2. Using the selection criteria previously mentioned, breeders selected the 23 best elite lines among the 150 ears over three cycles of selection from late 1978 to late 1979. Those lines were tested for four seasons from early 1980 to late 1981 in a randomized complete block experiment with four replications. Selection was completed in late 1981, and the variety HDK4 was produced and distributed to growers in 1982.

Variety Testing

The objective of this work is to evaluate the adaptability and yield capacity of varieties received from international institutions. In 1984 we cooperated with

CIMMYT in varietal testing, receiving six Experimental Variety Trials (EVTs). In mid-1985 EVTs 12A, 13, 14A, and 14B were tested, and EVTs 16A and 16B are scheduled for testing in early 1986 at Naphok Research Center.

EVT 12A--This EVT consisted of 10 entries from CIMMYT and two local check varieties (HDK3 and HDK4). It was planted in May 1985 and harvested in September 1985. Germination and initial vegetative growth were generally unsatisfactory because of lack of soil moisture. A considerable number of plants germinated secondarily after receiving enough rainfall, but this resulted in comparatively shorter plant and ear heights.

The analysis of variance of grain yield, however, showed highly significant differences among the varieties. The coefficient of variation was not high (CV = 11%).

Ferke (1) 8243 gave the highest yield (4278 kg/ha), and Ferke 8243 yielded 4227 kg/ha. The check, HDK3, gave 3792 kg/ha (Table 2). These results are from the first season only, and the varieties should be further tested.

EVT 13--This EVT consisted of 17 entries from CIMMYT and 2 local checks (HDK3 and HDK4).The trial was planted in May 1985 and harvested in November 1985 (Table 2). Altogether, nine varieties yielded better than HDK3, the top three being Pichilingue 8224 (4033 kg/ha), Across 7728 RE (3787 kg/ha), and Across 8136 (3784 kg/ha). Because of the high yields, this trial will be requested next season.

EVT 14A--This trial was composed of 13 entries from CIMMYT and HDK3 and HDK4, the local checks; it was planted in May 1985 and harvested in September 1985.

At the vegetative phase, all varieties were infected with downy mildew (Sclerspora spp.) and Helminthosporium spp. Severity of both diseases was scored as 2 on a 1-5 scale (1 indicates no disease and 5 very heavy infection). The coefficient of variation was 11.5% (Table 2). The trial should be repreated.

EVT 14B--Two checks (HDK3 and HDK4) and 12 varieties from CIMMYT comprised this trial, which was planted on the same date as EVT 14A. At flowering all varieties were attacked by Septoria maydis and aphids. Both the disease and insect attacks were rated 2 on a 1-5 scale (1 is no disease or damage and 5 is heavy infection or infestation). The analysis of variance of grain yield showed highly significant differences among varieties, and the coefficient of variation was not high (CV = 9.3%).

San Jeronimo 8232 gave the highest yield of 4.9 t/ha, followed by Ikenne (1) 8249 at 4076 kg/ha and Ferke (1) 8223 at 4051 kg/ha. The check HKD4 yielded 3690 kg/ha (Table 2). This trial should be repeated.

Table 2. Results of four Experimental Variety Trials (EVTs) Naphok Research Center, 1984

EVT and entry	Yield (kg/ha)	Days to silk	Ear height (cm)
EVT 12A			
Ferke (1) 8243	4278	58	118
Ferke 8243	4227	58	128
Across 7729RE	3920	57	109
Checks:			
Haddokkeo HDK3	3792	55	123
Haddokkeo HDK4	3103	57	123
EVT 13			
Pichilingue 8224	4033	55	136
Across 7728RE	3787	56	113
Across 8136	3784	56	117
Check:			
Haddokkeo HDK3	3446	57	133
EVT 14A			
Dharwar 8126	3874	52	100
Piura 8126	3840	53	107
Check:			
Haddokkeo HDK3	3342	54	110
EVT 14B			
San Jeronimo 8232	4947	54	104
Ikenne (1) 8249	4076	55	90
Check:			
Haddokkeo HDK4	3690	52	128

Varieties released in the last 10 years--Presently, four varieties are approved for cultivation: HDK3, HDK4, HDK 4-37, and Lao Soung. The latter two can be grown in both the wet and dry seasons, though yields in the wet season are generally low because of downy mildew. Yields obtained on the experiment station reach 3.5-4.3 t/ha, whereas yields obtained by farmers are much lower (1.2-2.0 t/ha) (Table 3).

Agronomy/Production

In the dry season of 1984-85, an experiment with eight treatments was conducted to determine the reponse of maize to various rates and formulations of N, P, K, and CaO at Naphok Research Center. The soil is characterized as slimy clay, with a pH of 5.4-5.6, 1.2-1.4% organic matter, 7.1 ppm assimilable phosphorus, and an aluminum exchange capacity of 0.3-0.7 mg/100 g soil.

The experiment was a randomized complete block with four replications. Plots were four rows, 8 m in length. Seed of variety HDK4 was planted during December 1984 in hills spaced 10 cm apart in rows 80 cms apart. Excess seed was planted and stands thinned to one plant/hill two weeks after planting. The two center rows of each plot were harvested after plants at the end of each row were discarded.

Table 3. Characteristics of Laotian maize varieties in the Regional Maize Trial, Indonesia

	Variety			
Characteristic	HDK3	HDK4	HDK 4-37[a]	Lao Soung[b]
Flowering (days)				
Male	50	55		53
Female	54	60		57
Plant height (cm)				
Male	193.7	192.7		220.8
Female	110.3	106.1		130.4
Number of leaves	11	13		14
Maturity (days)	100-115	110-120	110-120	110-115
Yield (t/ha)	3.50	3.80		4.3

[a] HKD 4-37 is a new line selected from HDK4.

[b] Lao Soung is a local cultivar.

The results indicated that 1 t CaO improved yields 420 kg/ha (Table 4). Applying 90 kg N/ha and 60 kg/K_2O/ha with CaO at a rate of 0.8-1.6 t/ha gave high yields (6.055-6.338 t/ha). This experiment must be repeated at least two more times.

Seed Production

Presently, there are four public seed multiplication farms in the country: Haddakkeo Research Station, Naphok Seed Multiplication Center, Thasano Seed Multiplication Farm (Savannakhet Province), and Phone Ngam Seed Multiplication Farm (Champassak Province). The Haddakkeo Research Station is responsible for producing foundation seed. At Naphok Seed Multiplication Center and the two farms, certified seed is produced and distributed to growers.

The seed program at Haddokkeo, Thasano, and Phone Ngam farms received assitance from the European Economic Community (EEC) in the form of a grant in 1984. Even so, seed supplies are insufficient for the country's entire maize-producing area. The Department of Agriculture has threrefore tried to encourage farmers to save their own seed, and the public seed multiplication farms have contracted with cooperative farms to produce quality seed for growers.

Table 4. Response of maize variety HDK4 to NPK fertilizer and lime (CaO), Naphok Research Center, 1984-85 dry season

Treatment[a]		Yield (kg/ha)
1	0 t/ha CaO	3716
2	0.84 t/ha CaO	4209
3	1.68 t/ha CaO	4911
4	2.52 t/ha CaO	5046
5	3.36 t/ha CaO	5235
6	4.20 t/ha CaO	5544
7	0.84 t/ha CaO + 90 kg N/ha, 60 kg K_2O/ha + 60 kg P_2O_5/ha	6055
8	1.68 t/ha CaO + 90 kg N/ha, 60 kg K_2O/ha + 60 kg P_2O_5/ha	6358

[a] As basal, all CaO, P2O5, and 30 of N; as top dressing, 30 + 30 of N (twice).

CIMMYT'S Expanded Maize Improvement Program

R.L. Paliwal, Associate Director, Maize Program, CIMMYT, Mexico

CIMMYT's Maize Improvement Program is directed toward the needs and problems of developing countries. It is hoped that the ultimate result of the Program's research will be to increase the options available to farmers for raising the productivity of resources they commit to maize production. In working toward that end. CIMMYT maize scientists cooperate closely with their colleagues in national programs. The Program is designed to:

* Provide an overall maize research strategy for serving maize-producing regions and/or countries that are at different levels of development and research capability

* Continuously develop and improve maize germplasm to meet current and future needs. and provide a smooth system for delivering germplasm to and from national programs

* Conduct exploratory. innovative maize research

In working toward the second goal, the Program engages in the following activities, with both normal and quality protein maize (QPM):

* Broadly based gene pools are developed and improved for specific characters and for different areas of the world.

* Populations are improved and refined with upgraded materials from specific pools.

* Superior, broadly adapted progenies are selected through multilocational testing, to continuously improve maize populations and to select superior families for developing experimental varieties.

* Superior experimental varieties. which can be used by national programs as breeding materials or further refined for eventual release to farmers, are sent for international testing.

Most national programs with which the Maize Program collaborates have emphasized the development of open-pollinated varieties. The result of this cooperation is a wide array of superior germplasm for lowland tropical and subtropical maize-growing environments.

During the course of that joint work with national program scientists, the Maize Program conducted a critical search for research areas deserving greater attention. That investigation revealed several needs. For example, it became apparent that more work on developing germplasm tolerant of various stresses, such as aluminum toxicity and drought, was desirable. Increasing the diversity of germplasm suited to midaltitude and highland areas, particularly in Africa, required attention as well. Also, as some national programs shifted their resources to developing hybrid maize, and a new range of possibilities for using germplasm from CIMMYT and other organizations became apparent, a greater demand for CIMMYT's assistance in hybrid development emerged. In response to that demand, the Maize Program decided to support hybrid development more directly than it had in the past. Today I would like to discuss this aspect of the Maize Program in greater detail, because it is a recent expansion of maize breeding work that has numerous implications for national maize research programs.

CIMMYT's Work on Hybrids: An Overview

In the past, the Maize Program supported research on hybrids indirectly through its germplasm development efforts (some products of which could be employed in developing hybrids) and the assistance provided by staff of regional programs or bilateral projects. National programs' heightened interest in hybrid maize led the Program in 1985 to begin offering more direct assistance to national researchers interested in hybrid work.

The particular types of assistance provided by the Maize Program make it possible to address the needs of hybrid development without compromising CIMMYT's basic policies of 1) producing intermediate products for use by national programs and 2) strengthening the capacity of national program personnel to use these products efficiently. Our assistance takes three main forms: information, germplasm products, and training.

First, we compile information about inbreeding depression and heterotic patterns for both the gene pools and populations. Second, while improving the pools and populations, we select superior materials, take them through a couple of generations of inbreeding, and make the products available to national programs. Third, we are assembling detailed information for national program researchers and others on various techniques of developing hybrids, particularly nonconventional types. There is little published material on forming family, topcross, and varietal hybrids, and we consider it worthwhile to fill this information gap. Furthermore, we are convinced that these nonconventional hybrids, which are much easier to develop and produce than conventional types, may be a better option for developing countries that have started or expect to start hybrid programs.

To meet the needs of national programs, then, CIMMYT has started or will take up work in the following areas:

* Developing methods for efficiently integrating population improvement with hybrid development
* Generating information on the combining ability and heterotic patterns of maize gene pools and populations
* Developing new superior heterotic groups as a source of germplasm to form hybrids for various parts of the developing world and, through interpopulation improvement, maximizing the potential of heterotic populations for hybrid development
* Improving and developing maize germplasm tolerant to inbreeding stress
* Developing, evaluating, and utilizing early generation inbred lines
* Identifying and developing testers for future hybrid work
* Adapting elite temperate inbreds for use in tropical and subtropical combinations
* Developing methodologies for breeding nonconventional hybrids
* Developing methodologies for breeding QPM lines and hybrids
* Providing training in maize hybrid development at CIMMYT

The following sections detail what has been achieved in CIMMYT's hybrid work so far, and also discuss plans and options for future research.

Integrating Population Improvement and Hybrid Development

To derive either superior varieties or hybrids, it is extremely important to begin with superior source germplasm that is continuously improved through appropriate selection schemes. In the breeding programs of many developing countries, both varieties and hybrids are expected to play an important role, and breeding programs should be designed to develop each product efficiently. To generate superior varieties and synthetics as well as hybrids, specific procedures that link population improvement with hybrid development should be established. Such procedures will help national programs sustain a balanced and integrated population improvement-cum-hybrid development program. That kind of program would not only meet the needs of various categories of farmers, but would also provide them with options in their crop management systems.

CIMMYT's Maize Improvement Program currently handles a large number of gene pools and populations--46 normal and 23 QPM gene pools and populations--and is in a unique position to develop procedures integrating population improvement and hybrid development. For example, during the various steps in a population improvement cycle, it is possible to extract lines and families that may be good parents for nonconventional hybrids or for making synthetics. The improved varieties and synthetics can be used in intervarietal hybrid combinations. But regardless of the particular product the breeder desires, the availability of superior materials depends upon continuous and systematic improvement of source germplasm. For that reason, one cannot divorce the development of hybrids from the improvement of source germplasm.

Some specific examples of the complementarity of population improvement and hybrid development can be cited. First, better full-sib or half-sib families routinely identified in an interpopulation improvement program can be used to produce interfamily hybrids or a full-sib x S_1 line combination. Also, if two populations are known for their heterotic pattern, families in each population can be identified for subsequent use in interpopulation interfamily hybrids. Introducing an inbreeding cycle as one step in a population improvement program could help identify superior S_1 lines to be used in developing inbred lines. In a population improvement program such as CIMMYT's, which involves inbreeding and recombination cycles, it is possible to obtain preliminary combining ability estimates of S_1 or S_2 lines depending on the inbreeding stage at which those lines are recombined.

Interpopulation improvement schemes are particularly suited for integrating population improvement and hybrid development. Two schemes that can achieve this goal are reciprocal recurrent selection (Comstock et al. 1949) and full-sib reciprocal recurrent selection (Hallauer and Eberhart 1970).

Reciprocal recurrent selection and full-sib reciprocal recurrent selection are commonly used to improve two populations at the same time, and also to improve their cross performance. In addition, interpopulation improvement facilitates the development of inbred lines and other parents for varietal hybrids, line x variety hybrids, and family hybrids. Full-sib reciprocal recurrent selection has the added advantage of permitting the identification and development of single crosses in the shortest possible time.

Information on Combining Ability and Heterotic Patterns

The CIMMYT Maize Program presently handles 22 normal populations and 24 gene pools with tropical and subtropical adaptation, as well as 10 QPM populations and 13 QPM pools. The first attempt at CIMMYT to obtain information on combining ability and heterotic patterns in these pools and populations was initiated by E.C. Johnson in 1979-80. through the use of Tuxpeño and ETO (both well known for their combining ability) as testers. The results have been circulated to cooperators interested in this information.

Larry Darrah and his colleagues at the University of Missouri topcrossed CIMMYT tropical pools and populations with B73 and MO17. and found that Population 29 yielded significantly more when crossed to B73 than when crossed to MO17. Three other materials (Pool 26. Population 22, and Population 43) showed heterosis with both inbreds (Darrah et al. 1987). In an earlier study, A.F. Troyer of Pfizer Genetics also topcrossed several CIMMYT pools and populations with inbreds B73 and MO17. In that study Population 29 showed better heterosis with MO17 than with B73.

In other experiments done by various national programs (in Mexico Cortez et al. 1981; in Brazil Miranda and Vencovsky 1984 and Napolini Filho et al. 1981). the combining ability of some CIMMYT pools and populations with adaptation to particular regions was determined through a diallel mating system. Cortez et al. found that the largest significant heterotic effects were shown by Pool 19 x Population 21. Pool 19 x Population 49. and Pool 20 x Population 49. Surprisingly. Population 21 x Population 49 showed significant heterotic effects. The highest heterosis was evident in the cross combination Pool 23 x Population 43 and Population 29 x Population 43.

In the study by Miranda and Vencovsky (1984), Tuxpeño x ETO was the highest yielding cross. Based on two other studies in Brazil. the Brazilian composite Composto PBF and Population 22 (Mezcla Tropical Blanca) were identified to form one heterotic pair for interpopulation improvement.

All of these studies. and many more not listed here. have provided quite useful information. However. they are incomplete for our purposes because they do not include all CIMMYT pools and populations. Through the diallel mating system. the Maize Program will generate information as rapidly as possible on the combining ability of all CIMMYT pools and populations. Because it would require a great amount of work to acquire information on the cross performance of each material with all other materials. it was decided to group materials on the basis of maturity and adaptation. A diallel would therefore include all pools or populations falling in one group.

Using those criteria. seven different diallels were produced by S.K. Vasal. who heads the hybrid program at CIMMYT. An eighth set involved tropical x subtropical crosses using design-2 mating. The crosses were produced at Poza Rica or
Using those criteria. seven different diallels were produced by S.K. Vasal. who heads the hybrid program at CIMMYT. An eighth set involved tropical x subtropical crosses using design-2 mating. The crosses were produced at Poza Rica or
Tlaltizapan stations in Mexico during 1985A and were distributed widely for testing in Mexico. the USA, Nigeria. Zimbabwe. Guatemala, El Salvador. Colombia. Thailand, and a few other countries. Data have been received from enough locations to draw meaningful conclusions about the heterotic patterns in CIMMYT's tropical and subtropical maize germplasm. A summary of the performance across locations of some of the best crosses in the CIMMYT diallels is given in Table 1.

Developing Heterotic Groups

For a hybrid program to be successful. there is an obvious need to identify and improve suitable heterotic sources. The US hybrid program is largely based on two populations, Stiff Stalk Synthetic and Lancaster Surecropper. The Kenyan hybrid program is based on heterosis between Kitale Synthetic II and Ecuador 573, and in Brazil good heterotic sources have also been identified. For wider use in tropical areas. Tuxpeño x ETO is the one reliable heterotic group that has been the source of a large number of tropical hybrids.

Forming additional. divergent maize groups that could be used efficiently to produce hybrids would facilitate and simplify hybrid work in many national programs. In developing CIMMYT maize pools and populations. diverse germplasm was merged regardless of the heterotic behavior shown by intervarietal crosses. Most of the pools and populations thus contain complex, broad-based materials which have considerable interpopulation heterosis, but which fail to exhibit substantial heterotic effects in cross combinations. It is clearly necessary to begin producing germplasm with improved heterotic responses. In developing heterotic groups, information from the diallel analyses will be used. and lines will be preferred over heterozygous materials. But prior to including lines in heterotic groups. suitable. sufficiently divergent testers will be used.

In view of the germplasm needs of the lowland tropics, at least four heterotic groups may have to be formed. For subtropical germplasm, at least two heterotic groups may be formed. Once these are developed, they will be improved using appropriate interpopulation improvement schemes.

Table 1. Summary of the performance across locations of selected crosses in CIMMYT diallel studies, 1986

Trial type	Cross	Grain yield (t/ha)	Best-parent heterosis (percent)
Diallel-1 Early subtropical	Pop. 48 x Pool 27	4.63	113
	Pop. 48 x Pool 28	4.64	112
	Pop. 46 x Pool 30	4.47	110
	Pop. 46 x Pop. 48	4.43	108
Diallel-2 Interm. subtropical	Pop. 42 x Pop. 47	5.82	111
	Pop. 42 x Pop. 34	5.64	108
Trial 3 Tropical, subtropical	Pop. 32 x Pop. 44	6.65	113
	Pop. 43 x Pop. 42	6.85	111
	Pop. 43 x Pop. 44	6.71	109
Diallel-4 Tropical late yellow	Pop. 27 x Suwan 1	6.77	115
	Pool 26 x Suwan 1	6.60	112
	Pop. 24 x Suwan 1	6.97	110
	Pop. 24 x Pop. 36	6.98	110
Diallel-5 Tropical late white	Pop. 29 x Pop. 32	7.20	113
	Pop. 21 x Pop. 25	7.16	112
	Pop. 21 x Pop. 32	6.94	108
Diallel-6 Tropical early-interm.	Pop. 26 x Pool 21	7.01	110
	Pop. 23 x Pool 20	7.34	109
Diallel-7 QPM subtropical	Pool 33 QPM x Pool 34 QPM	7.43	110
Diallel-8 QPM tropical	Pop. 65 x PR 7737	6.77	120
	Pool 25 QPM x PR 7737	6.15	111

Source: Courtesy of S.K. Vasal.

Interpopulation Improvement

As noted earlier, interpopulation improvement schemes are designed to simultaneously improve heterotic populations and their cross performance. At CIMMYT, Tuxpeño (Population 21) and ETO Blanco (Population 32) have been taken out of international testing and will be handled in the reciprocal recurrent selection procedure proposed by Comstock et al (1949), with some modifications.

When additional heterotic groups have been identified, they will also undergo reciprocal recurrent selection. The S_1 lines will be developed during the 1986A season and evaluated in 1986B at Poza Rica. A sample of about 250 S_1s will be selected and advanced to S_2 during the same cycle (1986B). In 1987A, topcrosses will be produced for evaluation in 1987B at several locations, preferably where our regional program staff can assist. Based on data from these evaluations, superior S_2s (about 20% of the total) will be recombined in 1988A. Ensuing cycles will involve the recurrent steps of generating S_1s and S_2s, developing topcrosses, evaluating them, and recombining superior lines based on topcross performance.

Initially, an experimental variety from one population will be used as a tester against the other population, and vice versa. As the selection process continues, lines will be developed and made available to national programs. Later, inbred testers will be used.

Interpopulation improvement can generate the following products:

* Improved versions of the populations
* Experimental synthetics
* Line extraction and development
* Superior topcross hybrids
* Varietal hybrids
* Modified varietal hybrids
* Conventional single-cross hybrids

Improving Tolerance to Inbreeding Stress

How effectively and efficiently source germplasm can be used in developing hybrids depends on its ability to produce a high frequency of vigorous and productive inbred lines. Source materials that have been continuously handled in a full-sib, half-sib, or mass selection scheme may not have been improved for inbreeding stress. However, selection schemes that have a built-in inbreeding phase will help to improve materials for this trait.

Two studies conducted in Brazil provide a good basis for that assumption. Vianna et al. (1982) studied inbreeding depression in S_1 lines developed from 14 maize populations introduced from CIMMYT. Suwan 1, developed in Thailand through S_1 selection, showed less inbreeding depression than other broad-based pools and populations that were not subjected to S_1 selection. The S_1s developed from pools showed, on the average, higher inbreeding depression (51.56%) than the S_1s derived from populations (46.2%), which had undergone more improvement and had a narrower genetic base than the pools.

In another study of inbreeding depression in 32 Brazilian populations, Lima et al. (1984) also reported that average inbreeding depression was generally smaller for population-synthetics derived from inbred lines than for other broad-based composite populations.

Over time, CIMMYT's pools and populations can certainly be improved for tolerance to inbreeding by introducing an inbreeding phase as an essential step in the improvement cycle, or by initiating an intermittent selfing phase (once every three years) in the half-sib system through which the pools are improved. Additional work is needed, however, to permit a large number of good lines to be extracted from the source germplasm. We propose to begin developing synthetics with a narrow genetic base and inbreeding stress tolerance. During the inbreeding process related to line development, a sample of about 25 S_2 or S_3 lines that successfully tolerate inbreeding will be recombined and advanced to the next breeding generation. New lines will be extracted again, and the superior S_2 or S_3 lines that remain will be recombined. This recycling process will continue and through visual selection these synthetics will be improved for inbreeding tolerance.

Developing, Evaluating, and Utilizing Early Generation Inbred Lines

The range of germplasm available at CIMMYT includes improved populations, gene pools, experimental varieties, synthetics, special pest-resistant pools, and selected full-sib and half-sib families, all of which can be used as sources for inbreds. Every year, the pool and population improvement process (in which selfing is an important step, taking place during each selection cycle) generates about 20,000 S_1s. These are available to the hybrid program for screening and evaluation. Selfing can also be done in bulk populations, pools, experimental varieties, and special-trait materials that are not being regularly improved through progeny selection.

Superior full-sib or half-sib families currently undergoing population improvement are an additional source of inbreds. Elite families known to produce good lines can be resampled, but this is possible only in populations structured as full-sib or half-sib families where there is an inbreeding phase in the selection process.

At least in the early generation of inbreeding, probably up to S_3, each selected ear will be handled on an ear-to-row basis. Past the S_3 stage, lines can be advanced through sibbing or selfing, depending upon their uniformity. These early generation inbred lines will be subjected to various stresses at different stages of development. For example, from the S_1 stage onward inbred lines will be subjected to high population density. Each line will be planted at two densities. The front half of the row (low density) will be used for observations and recording data, including yield evaluation at harvest. The second half of the row (high density) will be used to judge stalk quality, root lodging, increased disease incidence, and nicking. Pollinations will be restricted to the high-density area of the selected lines.

Materials will also be evaluated under disease and insect pressure. Lines that have tolerated inbreeding fairly well and are reasonably vigorous, productive, and agronomically acceptable will be further screened under artificial infection for important diseases (such as stalk rots, ear rots, and leaf blights). Subtropical lines will be screened for Turcicum leaf blight (Helminthosporium turcicum) at Poza Rica during the winter season, and for common rust (Puccinia sorghi) at El Batan. Materials will also be screened for resistance to insect pests such as fall armyworm and various borers.

Evaluating Combining Ability of Inbred Lines

During the population improvement process, lines will be visually evaluated to obtain a preliminary idea of their per se performance. Lines that survive inbreeding for at least three generations and still look promising will then be systematically studied for general combining ability. At first, for lack of more appropriate testers, experimental varieties will be used, but over time a wide range of proper testers will be developed. These will include some narrow-based testers, such as lines and families undergoing mild inbreeding.

Topcross evaluations will be done in replicated trials at no fewer than four sites, including one in Mexico. The other locations will be chosen from areas where CIMMYT regional program staff have been posted. Lines found to have superior combining ability will be made available to national programs.

Developing and Identifying Appropriate Testers

The development and identification of suitable testers is critical for a hybrid program. Though it is possible to use some general testers in the early stages of the program. in the long run more specific testers are necessary. The following types should be considered:

* Lines that can be used in the interpopulation improvement program to screen the S_1 lines, to facilitate heterotic grouping of new lines, and to separate and merge early generation inbred lines in different heterotic groups

* Experimental varieties that can be used for evaluating general combining ability and identifying topcross hybrids and modified varietal crosses

* Families to serve as testers for evaluating combining ability and identifying line x family and interfamily hybrids

* Single crosses for identifying three-way crosses, double topcrosses, and modified double topcrosses

* Temperate lines to be used as testers in tropicalizing temperate lines

As the hybrid program develops, we hope to identify suitable testers in the categories indicated above for developing both conventional and nonconventional hybrids.

Nonconventional Hybrids

In CIMMYT's hybrid program, considerable time and other resources will be alloted to developing methods for producing nonconventional hybrids. These differ from conventional hybrids, in which all parents are long-term inbreds, in that nonconventional hybrids have at least one parent that is not an inbred line, and generally have two or three components in their pedigrees. Some types of nonconventional hybrids are:

* **Varietal hybrid:** A cross of two populations, varieties, or synthetics

* **Family hybrid:** Inter- or intrapopulation family cross

* **Topcross hybrid:** Line x variety, line x synthetic, or line x family

* **Double topcross hybrid:** Single cross x variety, single cross x synthetic, or single cross x family

Nonconventional hybrids have several advantages over conventional types. It is easier to develop. maintain. and produce seed of nonconventional types. Also. the female parent has a good seed yield, making hybrid seed costs lower. Family crosses have the advantage of uniformity, superior yield, and are as easy to produce as single-cross hybrids. without their maintenance and production problems. The advantages of nonconventional hybrids might make their production a good catalyst for the development of sound seed enterprises in many Third World countries. The exchange of germplasm would also be comparatively free and open, which is not usually the case with inbred-based hybrids.

We believe that nonconventional hybrids may be a good option--an intermediate step--for many national programs that want to start hybrid programs. Several examples of successful nonconventional hybrids may be cited. In India double topcross (single cross x variety) hybrids produced in 1962 are still the most popular hybrids in the northern plains. In Guatemala eight nonconventional hybrids have been released and are doing very well (Table 2). Varietal crosses SMC101 and SMC102 (Population 28 x Suwan 1 and Population 36 x Suwan 1) have been successful in the Philippines, and in Kenya varietal crosses from populations 32 and 49 have performed well for the lowland tropics. Brazil has released three varietal

Table 2. Nonconventional hybrids released in Guatemala, 1974-83

Pedigree	Type of hybrid	Year released	Name
Tuxpeño-1 x ETO Bco.	Intervarietal	1974	T-101
A-2 x 27-44	Family x variety topcross	1979	HA-28
(22-105 x 21-170) x 3805	Family cross x variety double topcross	1979	HB-11
(29-244 x 23-86) x 43-46	Family cross three way	1980	HB-33
(Pool21-6 x 24-214) x 26-49	Family cross three way	1983	HA-44
(22-100 x 29-5) x 43-68 1-1-1	Family cross x line double topcross	1983	HB-83

crosses. BR 300, 301, and 302, containing germplasm from CIMMYT populations and Suwan DMR. A full-sib family hybrid was released in Ecuador, and in China a line x variety cross is available to farmers. Yet another intervariety cross, for winter maize in the Punjab, has been released in India.

Tropicalizing Superior Temperate Inbred Lines

Several of CIMMYT's pools and populations contain varying doses of temperate germplasm. Some of these materials have been crossed to promising tropical sources to evaluate their potential for hybrid development. It may also be worthwhile to attempt to tropicalize some elite temperate lines that are widely used in the USA and other parts of the world, and six to eight lines will be selected for that purpose. Tropical germplasm will be combined with the temperate materials in a breeding procedure that involves backcrossing, intervening recombination cycles, and carefully chosen selection environments. Testcross evaluation methods will be used to detect lines that are more closely related to the original temperate lines, but which have developed more tropical adaptation.

Developing QPM Lines and Hybrids

With respect to QPM hybrids, CIMMYT has the advantage of available germplasm, the necessary equipment and laboratory facilities, and expertise in QPM work. Much of the QPM germplasm with a hard kernel texture was developed at CIMMYT. These lines are substantially better than the original soft-endosperm opaque-2 materials that had low yields, soft kernels, dried slowly, and were highly susceptible to ear rots and damage by storage pests.

In developing improved QPM germplasm, a combination of two genetic systems has been used, one involving the opaque-2 gene and the other the genetic modifiers of the opaque-2 locus. To form QPM hybrids, procedures will have to be worked out for expediting the development of QPM lines and their subsequent use in hybrid combinations. Developing QPM lines from source QPM germplasm is the most rapid approach and the one least subject to error. QPM lines can also be developed through the conversion of normal lines and of soft opaque-2 to hard endosperm. In the work on QPM hybrids, some effort will also be devoted to identifying simply inherited modifiers; their identification will aid considerably in converting normal or soft opaque-2 lines to hard-endosperm QPM lines.

Training in Hybrid Maize Development

Training in hybrid development has not been prominent in CIMMYT's in-service maize improvement courses. However, with the initiation of the hybrid maize program, trainees can now be exposed to different aspects of breeding maize hybrids, to the maintenance and multiplication of lines, and to the production of conventional and nonconventional types. It is hoped that this training will not only facilitate variety and hybrid development in national programs, but will also help accelerate the establishment of efficient seed production programs in the developing world.

Discussion

M.Q. Chata: Is CIMMYT preparing procedural guidelines for developing and testing maize hybrids?

R.L. Paliwal: CIMMYT plans to publish a bulletin on development and production of nonconventional maize hybrids, to be followed by a bulletin on QPM hybrids.

J. Singh: What is the relative level of inbreeding depression in selected and unselected populations?

R.L. Paliwal: At CIMMYT we do not have specific data on inbreeding depression in S_1 lines developed from original unselected populations. However, there is considerable evidence to show that S_1 lines developed from improved populations are better than those from unimproved populations, and recovery of good lines from advanced germplasm is also better. Breeders from institutions that make use of CIMMYT populations for extracting inbred lines have confirmed this observation.

B.D. Agrawal: What is a modified varietal hybrid? Is it desirable to advocate hybrid programs for the developing countries where CIMMYT works, where maize yields range from 1 to 2 t/ha? And if hybrids are developed for those areas, how can the availability of quality seed be assured?

R.L. Paliwal: We define modified varietal hybrids as those formed from two experimental varieties or synthetics, as compared to pool or population bulks.

For most developing countries that wish to begin work on hybrids, a judicious production of open-pollinated varieties and hybrids is the best solution, as we have seen here in Indonesia. The next issue of CIMMYT Maize Facts and Trends will discuss some alternatives open to national programs that wish to start hybrid programs, and will also discuss which circumstances are likely to favor the adoption of hybrids by farmers. We hope that the production of nonconventional hybrids will act as a catalyst for seed production and seed enterprises in developing countries, and that this in turn will accelerate the production of good quality seed of open-pollinated varieties as well.

R.P. Bosshart: The March 1986 issue of Crops and Soils reported that since 1971 a mutant extra-leaf-above-the-ear gene has been developed in an inbred, and is presently available for licensing to maize breeders through Hughes Hybrids, Woodstock, Illinois. At 70,000 plants/ha, yields of a hybrid with the extra-leaf gene were 60% over those of conventional hybrids. Have you heard of this gene yet? Does CIMMYT have something comparable in its germplasm bank?

R.L. Paliwal: Yes, we have heard of this gene, but do not have such germplasm in our collection. I personally doubt the claim that yields increased 60%.

M.M. Lantin: Now that you are engaged in the development of hybrids, will you change your policy regarding the flow of germplasm (parental lines, families) to private seed companies? Can the national programs be given a higher priority?

R.L. Paliwal: Our policy on sharing germplasm remains unchanged, and national programs will receive priority in the distribution of inbreds as well as any other limited germplasm. It should be appreciated, though, that national programs will also have to be patient, since CIMMYT will need time to meet requirements for inbred lines.

C. Chutkaew: When will CIMMYT hybrid maize be put into international trials?

R.L. Paliwal: A program for testing hybrids is still under consideration, and a final procedure has not yet been established. Any suggestions from national programs in this matter would be very welcome.

S. Khan: You said that you intended to test the combining ability in S_2s and S_3s next year. During inbred development, when is the best time to determine combining ability?

R.L. Paliwal: In the family improvement part of our population improvement program, two stages are involved. The first is selfing selected full-sib families; 3-4 selfs are developed from each family. Second, the best S_1s are selected visually, and the selected S_1s recombined through bulk pollination with selected S_1 families. This is the equivalent of a topcross. In the following cycle the recombined S_1s are grown on a family basis. These are examined visually to obtain a preliminary idea of their combining ability. Those S_1 lines that appear to be poor on the basis of visual evaluation, as well as those that do not perform well when recombined, are discarded for hybrid work. Only selected S_1s are advanced to the S_2 generation. At S_3 we plan to make a more precise general combining ability test and distribute to national programs only those that combine well.

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Seed Company Reports

An important feature of the Second Asian Regional Maize Workshop was presentations by four seed companies (Pioneer, Cargill, Ciba-Geigy, and Dekalb Pfister) that are active in Asia. Those companies are making important contributions to maize research and seed production in the region, and their participation in the workshop did much to promote cooperative, fruitful relationships between them and the various national maize research programs. Here we present short versions of the presentations made by Ciba-Geigy and Dekalb Pfizer representatives.

Ciba-Geigy Seeds in Southeast Asia

Kriangsak Suwantaradon, Ciba-Geigy (Thailand) Ltd.

Ciba-Geigy is a Swiss company based in Basel. It started in seeds during May 1974 by acquiring Funk Seeds International, a US company based in Bloomington, Illinois. Subsequently, the company established research and development programs in other important maize- and sorghum-growing countries. Its objective is to develop crop varieties that are capable of producing high and stable yields of quality products under variable growing conditions. In Southeast Asia, where the seed industry is still at an early stage of development, Ciba-Geigy has already established a seed business.

Our company is research oriented. Its seeds subdivision spends a large amount of its resources on research and is increasing its number of research stations. Currently our R & D Seeds activities take place in 13 countries at a sizeable number of breeding stations. Two main policies that have played major roles in the company's progress in the seed business are: (1) decentralization of breeding programs, which enables plant breeders to produce varieties that meet the wide spectrum of requirements in different growing areas, and (2) worldwide exchange of information and materials among breeders in different breeding stations and national programs.

The Southeast Asian program is fully integrated into the company's overall system and has access to all the genotypes it produces. In our seed activities, we concentrate mainly on maize and sorghum. Sunflower, soybean, and cotton are also of interest to some countries but not in Southeast Asia. We started working in Thailand during 1981 and now have a fully operational, 36-ha breeding station there, which is doing research for other countries in Southeast Asia as well. We have identified maize and sorghum hybrids that we plan to introduce into the market in the near future.

Dekalb-Pfizer Genetics: Tropical Maize Research

Glenn Robison, Dekalb-Pfizer Genetics

Maize research at Dekalb-Pfizer is divided into two categories (temperate and tropical) because of the difference in natural adaptation of the germplasm grown within these two climatic zones. Research for the temperate zone is conducted at 31 locations in the USA and also in Argentina. Australia. Canada. France. Italy. and Spain at latitudes ranging from 31 to 48 degrees in the northern and southern hemispheres.

Dekalb-Pfizer Genetics is engaged in hybrid seed production and marketing in several tropical countries through licensed producers or partnerships. as indicated below.

Country	Commercial company
Brazil	BRASKALB Agropecuaria Brasileira Ltda.
Indonesia	P.T. Bright Indonesia Seed Industry
Mexico	Semillas Hibridas S.A. de C.V.
Thailand	Bangkok Seeds Industry Co. Ltd.

In the USA Dekalb-Pfizer Genetics develops germplasm, produces hybrid seed. and takes it to the market place. In many other countries. however. the company prefers to concentrate on germplasm development and to rely on local partners to produce and market the improved product.

Among our primary considerations in establishing new hybrid seed research operations are:

* Potential market size
* Political environment favorable to capital investment
* Level of agricultural technology
* Trained personnel
* Proximity to existing operations

Our current operations are located in tropical countries that have sizeable areas of maize production (Table 1). With the exception of Brazil. hybrid seed is not widely used in those countries. It appears. however. that Thai farmers are becoming more accustomed to purchasing new seed each year. judging from the high proportion of maize area planted to newly purchased nonhybrid seed (chiefly Suwan 1). and it is anticipated that this open-pollinated seed will soon be replaced by hybrid seed. High-quality seed of varieties is just now being introduced in sufficient volume in

Indonesia, and we expect to observe there a trend similar to that in Thailand of increased purchase of improved variety seed and subsequent replacement of varieties by hybrids.

Although seed of improved varieties is used in Brazil and Mexico, neither private nor public institutions are producing or marketing significant volumes of it. Instead farmers have maintained their own seed from year to year.

Trained personnel are one of the most important requirements in a hybrid seed venture. Some of the activities and positions requiring specially trained personnel are listed below:

- Research
  - Breeders
  - Breeder's assistants
  - Agronomists
  - Pathologists
  - Entomologists
- Foundation seed production
- Seed production and conditioning
- Distribution and marketing
- Extension

Dekalb-Pfizer's stations have been placed at strategic locations in the tropics and subtropics, so that we can develop germplasm with potential adaptation to growing conditions in most Asian countries. The stations are located at 8, 15, 20, and 28

Table 1. Use of improved maize seed in selected countries, 1985

Countries	Maize area (000 ha)	Percent of area planted to hybrids	Percent of area planted to improved varieties
Mexico	8400	15	less than 1
Brazil	11,000	65	less than 1
Thailand	1700	6	39
Indonesia	3200	1	1

degrees latitude (Table 2) and range in elevation from 20 to 1500 m above sea level. Those latitudes approximate the ones at which Asian countries are located. with the exceptions of Pakistan and most of China. which have temperate climates.

Dekalb-Pfizer's oldest breeding program for the tropics is the one in Mexico. which was started in 1971 and provided a source of breeding material for the Brazilian and Thai programs, both initiated in 1979.

Although the germplasm developed at 20 degrees latitude in Mexico proved to be relatively well adapted in Thailand. certain additional requirements had to be met. including resistance to downy mildew and different grain type preferences. Most of the germplasm developed by the Mexican program had white grain and ranged in texture from medium dent to dent. whereas in Thailand farmers prefer yellow or orange flints. Before the Mexican lines could be used in Thailand. their grain color and texture had to be converted. and they had to be crossed with a source of resistance to downy mildew.

Since germplasm from one location shows a fair degree of adaptation to another. routine exchange of germplasm is one of the key features of breeding programs for the tropics. Each year new elite inbreds used in new commercial or precommercial hybrids are exchanged between programs. as are potentially useful segregating materials, which can then be selected in multiple environments. Elite inbreds from tropical programs are increased and maintained in Florida. Those inbreds are recombined with temperate germplasm in Georgia within a program for selection of earlier segregates to be used in the temperate zone and later segregates to be used in tropical climates.

Table 2. Tropical and subtropical maize breeding stations of Dekalb-Pfizer Genetics

Location	Year established	Latitude	Elevation (m)
Mexico			
Guadalajara	1971	20° N	1500
San Juan de Abajo	1979	20° N	20
Brazil			
Barretos	1979	20° S	550
Passo Fundo	1979	28° S	678
Thailand			
Salangpan	1979	15° N	200
Indonesia (planned)	1987	8° S	64

In addition, a set of more than 250 inbreds used in commercial and precommercial hybrids in tropical and temperate zone countries worldwide is grown annually in each country to monitor reactions to pathogens and insects. This program (the Uniform Global Maize Resistance Assessment Project, directed by pathologist Dave Smith) ensures the exchange of elite germplasm among all breeding programs in addition to providing comprehensive information about its reaction to diseases and insects. So far, unique resistances have been identified for southern corn rust, maize rough dwarf virus, and maize streak. The systematic exchange of germplasm makes it possible over a period of two or three years to determine the reaction of new germplasm to all diseases occurring in the countries where the programs operate (Table 3).

Table 3. Diseases for which resistance selection is conducted in the Uniform Global Maize Resistance Assessment Project

Country	Location	Disease
Brazil	Barretos	Northern leaf blight Southern leaf blight Bacterial soft rots Rusts
	Passo Fundo	Southern leaf blight Northern leaf blight Rusts Viruses
Thailand	Salangpan	Asian downy mildew
Mexico	Guadalajara	Head smut Fusarium Gibberella ear rots Stalk rots
	San Juan de Abajo	Northern leaf blight Southern leaf blight Common rust Tropical rusts

Our partners in Thailand and Indonesia, the Charoen Pokphand Companies, have elected to begin with improved varieties rather than hybrids in introducing improved seed to farmers. This approach allows farmers to gain an appreciation of improved seed at lower cost and to learn about improved farming techniques (such as application of fertilizers, herbicides, and insecticides) under the guidance of company extension personnel. Farmers are realizing sufficient gains from genetically true seed over the seed they select themselves (which is lower in germination and vigor) that they are willing to buy new seed each year. After farmers have modified their practices to maximize returns from seed of improved varieties, they are ready to benefit from the higher yield potential of hybrids. In the process seed company personnel have the opportunity to learn production, processing, and distribution techniques with varieties before attempting to handle the more difficult business of hybrid seed production.

In Thailand we are currently marketing the hybrid CP-1, which is similar to the variety Suwan 1 in maturity, height, and stalk quality and yields 18% more on the average (Table 4), an increase that is sufficient to raise farmers' return above the higher seed cost. We anticipate that the second generation of hybrids now being developed for Thailand will surpass Suwan 1 in yield by 25 to 30%, giving farmers an even greater incentive to use hybrid seed.

In Indonesia CP-1 outyields the open-pollinated variety Arjuna (Suwan 2) by about 28% (as determined in 10 trials conducted during 1983-84) but is later maturing. Since some farmers prefer shorter season cultivars to facilitate multiple cropping, the development of earlier maturing hybrids will be an objective of the new Indonesian breeding program.

Table 4. Comparison between the yield of CP-1 and that of Suwan 1 in Thailand

Year	Number of trials	Yield difference (%) CP-1	Suwan 1
1982	8	118.0	100
1984	30	116.5	100
1985	30	119.8	100

In the initial phase of a new tropical breeding program, the the sequence of events is generally as follows:

1) Determination of heterotic patterns among adapted varieties

2) Extraction of inbreds from the most adapted and heterotic varieties

3) Production and testing of double-cross hybrids developed from those inbreds

4) Hybrid release

Our tropical programs, now in the second phase, are engaged in the activties listed below:

1) Recombination of the best inbreds developed in the initial phase and extraction of second-cycle lines

2) Introgression of temperate germplasm by way of crosses between elite tropical and elite temperate inbreds

3) Continued recycling of elite inbreds

4) Consideration of three-way and single-cross hybrids as the vigor of elite inbreds from second-cycle breeding increases

The performance of new inbreds being developed in the second phase of our programs indicates that it is possible to make considerable progress from second-cycle breeding (the recombination of inbreds extracted directly from open-pollinated varieties). Second-cycle tropical lines show significant improvement in agronomic fitness as well as in combining ability. Moreover, the introgression of temperate into tropical germplasm via crosses of elite inbreds is proving to be far more successful than previous efforts with varietal crosses. Crossing elite temperate with elite tropical inbreds is an excellent method of recombining the reduced plant and ear height and combining ability of temperate lines with the disease resistance and climatic adaptation of tropical lines.

Our tropical maize breeding program at Salangpan, Thailand, is typical of our other operations in the tropics. That program, under the direction of Anek Silapapun, conducts two or three nurseries per year (with a total of 12,000 nursery rows), maintains trials at four outlying locations, and tests 1750 hybrids each year. Some of the germplasm being used in the program is Tropical Late Yellow Dent, Suwan 1, Arjuna, CIMMYT Pool 24, Antigua, Nariño, Tuxpeño, and ETO. The program's objectives are to improve yield, disease resistance (especially to downy mildew), standability, grain quality, and husk cover; reduce plant and ear height; achieve faster drydown; and examine the economics of seed production.

Discussion

Gonzalo Granados: How did you arrive at the figure of less than 1% for the area planted to improved varieties in Mexico?

Robison: That figure represents the area planted annually with newly purchased seed of improved varieties and excludes the area planted with improved variety seed that the farmer has saved from previous crops.

Field Visits and Discussion of Regional Issues

The country and seed company reports given in foregoing pages provided workshop participants with a general, but fairly comprehensive, overview of maize research throughout the Asia region. Other workshop events were designed to encourage more detailed discussion, mainly on two topics: 1) the maize research program of Indonesia and 2) regional issues in maize breeding and agronomy. The first topic was dealt with in the course of various field visits: to the Muneng Research Station, the on-farm research (OFR) program of the Malang Research Institute for Food Crops (MARIF, see description below), and the P.T. Bright seed plant and contract growers' seed fields. During the visit to the Muneng station, participants saw demonstration plots of the best of their own germplasm and that of other countries in the region. Germplasm improvement and other regional issues were, of course, a recurring theme throughout the workshop, but they were treated more formally in two discussions, the minutes of which are given below.

The MARIF On-Farm Research Program

This program, which applies a farming systems perspective to research on maize-based farming systems, was initiated in Malang District during January 1984. Since then four cycles of on-farm trials have been completed, and a fifth was planted in February 1986. The trials have been complemented by various surveys (exploratory, formal, and so forth) and by field days for farmers.

Objective and Mandate

The main purpose of the OFR program is to develop practical recommendations for specific farm enterprises (crops or crop associations) that can be widely adopted by farmers within a particular target group and that show potential for increasing farm income. This approach is particularly suitable for maize and other palawija (secondary) that fall within MARIF's mandate, since it takes into account specific features affecting their cultivation. Those include the large variability in physical environment, the fact that the crops are mainly grown under rainfed conditions or on residual moisture in various crop associations, the high risk of erosion, and the great variety of end products.

Problem Identification and Research Approach

MARIF's maize OFR program had its origins in the release of the improved variety Arjuna during 1980. By 1984 Arjuna had been adopted by over 20% of the maize-growing farmers of Malang District, which possesses young volcanic soils. But even though the variety had shown a yield potential of at least 5 tons of dry grain per hectare at experiment stations, its yields were low in farmers' fields. The MARIF

OFR team found that farmers could raise their maize yields from 1.8 t/ha with local varieties to only 2.2 t/ha with Arjuna, using traditional management practices. The OFR program was initiated to find ways of solving that problem and of focusing research more directly on the farmers needs. The program has followed a research approach developed at CIMMYT and subsequently adapted to MARIF's institutional circumstances and to local physical conditions. The interdisciplinary team responsible for the program consists of plant breeders, crop protection specialists, agronomists, and agroeconomists.

Study Areas

MARIF works in two main study areas. In the first maize is grown as a monocrop on young volcanic soils at 400 to 700 m above sea level under rainfed (tegal) conditions during or after the rainy season. That area includes about 10% of East Java's estimated 100,000-ha maize area, of which 20,000 ha are in Malang District. In the first area the OFR team works closely with farmers in five villages, where on-farm trials are carried out under conditions that are representative of those throughout the study area. The team also conducts surveys among farmers in ten other villages within the same area. At present the team is refining its approach and verifying results in the first area and has begun working in a second area (the limestone area of South Malang District) where maize/cassava-based farming systems are practiced. In this second area an estimated 500,000 ha are planted to maize, 50% of East Java's total maize area.

Research Results

The primary outcome of the OFR program's work so far is that farmers conducting on-farm trials have been able to raise their maize yields from 1.8 tons of dry grain per hectare with traditional varieties and management to 4.8 t/ha with improved varieties and management. The yield increase raises farmers' net benefits from 198,000 to 573,000 rupiah per hectare, a nearly threefold increase. The results of benefit cost analysis show that the farmer receives an extra return of 12.5 rupiah for each additional rupiah invested. The improvements described here are obtained with only modest increases in input costs and with simple modifications in management practices. The OFR team anticipates that the improvements will be within the reach of most farmers in the region, since cooperating farmers (whose maize-growing conditions are representative of those throughout the study area) readily understood all aspects of the improved management practices.

Discussion of Agronomy Issues

M.Q. Chatha, chairman

E. John Stevens asked how the pot trials conducted by Indonesian researchers are related to fertilizer recommendations. J. Ph. Van Staveren replied that the trials were one step in a multistep procedure and that they precede fertilizer trials in plots. The purpose of the pot trials is to indicate major problems in the availability of nutrients. They enable researchers to estimate the level at which nutrient deficiencies can be expected to disappear. Joginder Singh asked whether the Indonesian program had found P fixation to be a problem and whether the pot trials provided an adequate basis for diagnosing nutrient problems. Van Staveren responded that P fixation was not found to be a problem and that the pot trials could serve as an aid to diagnosis, although the results would have to be confirmed in subsequent trials.

Singh asked whether Indonesian scientists had encountered any aflatoxin problems. Subandi replied that there probably were some problems but that no data were available on the occurrence of aflatoxin in Indonesia.

Chatha noted that a lack of uniformity in the hybrids in some demonstration trials that workshop participants had visited. Subandi responded that the results of those trials indicate that the hybrids have a definite yield advantage over the check.

J.M. Corpus asked about the involvement of extension in MARIF's on-farm research program. C. Van Santen replied that extension is involved in on-farm trials, particularly in identifying trial cooperators. The OFR program expects that extension's participation will expand but is still seeking ways of involving extension agents more deeply in OFR. They are already taking part in two-day training courses and within a couple of years will probably be conducting verification trials.

Other participants shared their own experiences with extension involvement in OFR. In Pakistan, for example, extension agents take part in both the planning and execution of on-farm trials, and they are given some OFR training. Subandi pointed out that in Indonesia there are not very many extension workers in maize; almost all are trained in rice production.

Richard Wedderburn invited the group from the Philippines to comment on their experiences in OFR. L.P. Olivia indicated that in her country extension's involvement in OFR takes various forms. Extension workers help coordinate verification trials and locate representative areas in which to conduct trials. They also convey feedback on variety and weed control trials from farmers to researchers. This information has led to various adjustments in the treatments used in the trials.

Additional efforts, particularly in training, are being made to better integrate extension and research, since the contribution of the former is essential in identifying farmers' needs and establishing priorities for research programs.

In the discussion that followed, Olivia asked why there were only two levels of fertilizer in MARIF's on-farm trials. Van Santen replied that higher levels gave no crop response and that the additional fertilizer was therefore a waste of money for farmers.

K.K. Lai added that in Nepal, where OFR has been conducted over the last 10-12 years, the involvement of extension has been critical, especially in the identification of trial cooperators. He emphasized the importance of focusing sharply on farmer's problems and of conducting variety and crop management trials to test the technologies available that show some promise for solving those problems.

J. Singh commented on the administrative aspects of OFR. Under whose auspices should this work be carried out, extension or research?

Chatha concluded the session by commenting on the appropriateness of the OFR approach being followed by the MARIF team and noting that similar approaches are being practiced in various countries of the region.

Discussion of Maize Breeding Issues

M.M. Lantin, chairman

Subandi explained various aspects of the Indonesian program's breeding strategy. Hybrids are being developed for more favored environments and early and late-maturing composites for marginal areas. Earliness is important because maize is frequently intercropped with rice. Subandi asked what CIMMYT is doing to develop tolerances to stresses such as aluminum toxicity and commented that better sources of those traits would be helpful in the development of improved germplasm for marginal environments. R.L. Paliwal replied that Center breeders are selecting in pools for agronomic quality and earliness (a drought avoidance mechanism) and improving a greater range of materials than before for drought tolerance. The Maize Program has also recently initiated work at Cali, Colombia, for developing germplasm that is tolerant to aluminum toxicity.

Gonzalo Granados commented further on the problem of aluminum toxicity, noting that it poses a problem on 850 million ha of maize in South America and the Caribbean. In Brazil researchers are testing cycles of selection for tolerance to aluminum toxicity. They have found that some races of maize show tolerance to high aluminum saturation but that the yield of those materials is low. Granados also pointed out that before taking action on this problem one must determine the level of aluminum saturation. Not until it reaches 60% does aluminum saturation become a serious problem.

K.K. Lal commented that the flow of germplasm between countries had tapered off some since the termination of the Inter-Asian Corn Program. Richard Wedderburn replied that any request for germplasm is honored and that therefore its exchange should be no less extensive than before.

M.M. Lantin asked whether there would be any change in CIMMYT's policy on germplasm exchange in view of the initiation of its new hybrid program. Paliwal replied that there would be no change whatsoever. The Center will continue distributing seed to any bonafide researcher, giving first priority to national maize programs. The only restriction on seed distribution is in the quantity, since supplies of some materials are limited.

Carlos De Leon mentioned the efforts of the regional program to gather information about the varieties and hybrids available in various countries and about means of obtaining them. He suggested that, in addition, regional staff can provide assistance in obtaining germplasm from outside the region (aluminum toxicity tolerant materials from Brazil, for example).

Paliwal commented that the region-wide germplasm demonstration plots at Muneng station are an excellent way of facilitating germplasm and information exchange and that they should be continued. Wedderburn added that the regional program will help with the distribution of seed of materials grown in the demonstration plots, since it might be problematic for some national programs to perform that task.

Joginder Singh pointed out that some of the materials in the demonstration plots do not perform as they do at locations in the countries where they were developed (in part at least because of the different disease and insect pressures). As a result, one can be misled about the performance of the germplasm. Any impression formed about the material can therfore only be an initial one and must be confirmed through further observation. Wedderburn added that the purpose of the demonstration plots was simply to help workshop participants become more familiar with the germplasm available.

There was some discussion of the problem of waterlogging in maize. Granados noted that the problem is common in Venezuela and suggested two possible solutions; one is to form ridges and the other to use resistant germplasm. He noted that La Posta is somewhat resistant to waterlogging. Paliwal added that one benefit the CIMMYT Maize Program hopes to gain from its work on wide crosses, which currently involves crossing maize with Tripsacum, is germplasm with tolerance to waterlogging as well as drought-tolerant materials.

Other participants commented on the importance of waterlogging in their countries, including Li Jingxiong, who said that selection for tolerance to this stress has been going on in China for the past five years.

Lal asked whether a program like the one for developing downy mildew resistance ought not be initiated to improve germplasm for resistance to virus diseases. De Leon replied that much more information than we now possess would have to be gathered on the severity of virus disease problems and on the virus strains involved.

Paliwal commented on improvement of protein quality and oil content in maize, noting some of the difficulties national programs would face if they were to embark on their own protein quality improvement programs. In most cases the costs of a laboratory equipped for large-scale protein analysis would be prohibitive. National scientists can probably save considerable time by starting with quality protein maize from CIMMYT.

Appendix 1: Workshop Program

Sunday, April 27	Arrival at Jakarta
	Check-in at Orchid Hotel
Monday, April 28	
0730-0900	Registration
0900-1000	Opening Ceremonies (Chairman, Sridodo)
	- Dr. G. Satari, Director General, AARD
	- Dr. D.L. Winkelmann, Director General, CIMMYT
	Country Reports (Chairman, Wedderburn)
1030-1100	- Malaysia
1100-1140	- Sri Lanka
1140-1220	- China
	(Chairman, Siwi)
1330-1410	- Indonesia
1410-1450	- India
1450-1530	- Nepal
	(Chairman, Granados)
1550-1630	- Pakistan
1630-1710	- Philippines
1710-1740	- Discussion
Tuesday, April 29	(Chairman, Subandi)
0730- 0810	- Thailand
0810-0850	- Vietnam
0850-0930	- Laos
0930-1000	- CIMMYT Hybrid Maize Program
	Seed Company Reports (Chairman, De Leon)
1020-1050	- Pioneer
1050-1120	- Cargill
1120-1150	- Ciba-Geigy
1150-1220	- Dekalb-Pfister
1315	Departure for airport (Jakarta to Surabaya)
1600	Departure for Batu Malang (Hotel Kartika Wijaya)
Wednesday, April 30	(Chairmen, De Leon and Wedderburn)
0700-0900	Visit to Muneng Research Station
0900-1200	Presentation of demonstration plots containing elite germplasm from Asian countries
	(Chairmen, Marsum and Subandi)

1300-1500	Presentation of Indonesian Maize Research Program
1530-1730	Departure from Muneng for Batau Malang
Thursday, May 1	(Chairmen, Marsum, V. Santen, and Van Staveren)
0800-1200	Presentation of the MARIF on-farm research program
1330	Departure from MARIF at Kendalpayak for Batu Malang
	(Chairmen, Soetaryo and Harrington)
1500-1700	Discussion of breeding and agronomy issues in the Asian region
Friday, May 2	(Chairman, Boonsue)
0700-0900	Departure from Batu Malang for Kediri
0930-1230	Visit to P.T. Bright Seed Plant at Pare and presentation of the P.T. Bright program
	Visit to contract growers' fields at Kederi
1330-1530	Departure from Kederi for Batu Malang
1600-1730	Discussion
Saturday, May 3	
0700	Departure from Batu Malang to Surabaya and Jakarta

Appendix 2: List of Participants

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