



P R O C E E D I N G S



U.S. UNIVERSITIES-CIMMYT MAIZE CONFERENCE

On Collaboration Toward Mutual
LDC Production Objectives

International Maize and Wheat Improvement Center
El Batan, Texcoco, Mexico

August 9-14, 1984



- PROCEEDINGS -

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MUTUAL LDC PRODUCTION OBJECTIVES

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Sponsors

The U.S. Agency for International Development
Bureau of Science and Technology, Agriculture Program

The International Maize and Wheat Improvement Center
Maize Improvement Program

The University of Minnesota
International Agricultural Programs

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PREFACE

This conference is a benchmark in the effort by U.S. University maize scientists to organize their resources and muster support for collaborative research within the U.S. Agricultural Community and within CIMMYT's Global Maize Improvement Program. This effort was initiated in 1977 in response to initiatives arising from the Title XII amendment to the Foreign Assistance Act of 1961. It has included at least seven formal meetings involving representatives from 15 universities and numerous informal meetings. A Collaborative Research Support Program proposed for maize was endorsed by BIFAD in 1981, but it was not funded. Further discussions among BIFAD, the U.S. AID Agricultural Office, CIMMYT and University representatives resulted in cooperative support for this conference.

Maize provides 24% of the world's cereal production for food and feed. It is the main dietary staple for millions of people in Mexico, Central and South America, and numerous regions of Africa, Asia and Southeast Asia. In these countries it is often the primary crop, frequently in shifting cultivation, and usually grown as a subsistence staple by small land holders with a minimum of technology. Grain yields in these less developed countries are about one-fifth of those in developed countries. An average annual yield increase of 1.0% is inadequate to provide for a population increasing at an average rate of 2.8% annually. Clearly there is a great and escalating need for more effective efforts to increase maize availability to these countries.

U.S. universities, along with the U.S. Department of Agriculture, have conducted basic and applied research on maize production and utilization for over a century leading to the development and support of a highly productive maize agriculture. CIMMYT is an applied research oriented institute and, with its predecessor organization, has been working for more than 40 years to increase maize production in the developing countries. Collaborative research programs involving U.S. and CIMMYT scientists would be highly complementary, but there has been too little opportunity over the years for collaborative efforts on a sustained basis. The impact of such investments could have immense benefit to maize production in developing countries and the United States.

The broad purpose of this conference was to initiate dialogue among CIMMYT, United States, and developing country scientists. Specific objectives were to: 1) identify specific collaborative research, technical assistance and training activities having high payoff potential, and 2) provide for a mechanism which would foster and support the organization and operation of long-term collaborative maize programs in problem areas of mutual concern and benefit.

These Proceedings record the summaries of discussions which took place among nearly 100 maize scientists and administrators from CIMMYT, U.S. universities, and developing countries. The discussions were organized around a comprehensive set of issues in major subject areas of the CIMMYT global maize program. CIMMYT senior headquarters staff presented an overview of their programs in each area. There were five discussion groups organized to include participants from the United States, developing

countries, and CIMMYT headquarters and outreach staff, with as much balance as possible among disciplines in each group. The chairperson syntheses and rappateur reports are intended to objectively record the results of these discussions. The views, suggestions, and recommendations presented are those of the individuals and the corporate discussion groups, and are not necessarily those of their employer, their organization, their country, or the sponsors of this conference.

EXECUTIVE SUMMARY

Research workers in the United States, CIMMYT and the developing nations have been aware of maize research being conducted by other scientists. There has, however, been only limited collaborative research between maize scientists in the United States with colleagues at CIMMYT and in developing countries. Collaborative research programs involving scientists in these three arenas could, if critically chosen and properly defined, be highly complementary and of immense benefits to agriculture in the developing nations and the United States.

This conference at CIMMYT headquarters in Mexico brought together, in a well-organized, interactive set of discussions, maize scientists and administrators from U.S. universities, CIMMYT (headquarters and outreach), the developing nations, U.S.AID and others. The guiding purpose was to jointly review the status of maize programs at CIMMYT and identify problems and issues amenable to solution through collaborative research, technical assistance and training activities, and which have a high potential for payoff. A second purpose was to jointly identify a mechanism to organize, secure support, and coordinate those activities necessary to the conduct of such collaborative efforts.

Conferees were divided into five interactive groups, with proportionate representations of disciplinary interests and organizational units. Following presentations by CIMMYT program leaders, these groups discussed specific issues in six topic areas:

- I. Germplasm preservation and genetic engineering techniques
- II. Broad base gene pools for major world production areas
- III. Development and improvement of populations by recurrent selection
- IV. Quality protein maize: breeding, nutritional aspects and adoption
- V. Characterization of biological and environmental stresses and development of selection techniques
- VI. On-farm research programs

Discussions were reported by each group, and then combined into topic summaries presented to the conferees as "Research Plans and Possibilities" for collaboration.

In the concluding session a panel of experienced administrators representing U.S. universities, CIMMYT and U.S.AID discussed mechanisms and financial support to carry out collaborative research identified and recommended by the conferees. A resolution proposed to capture the spirit of the conference and act upon its recommendations was unanimously adopted.

These Proceedings record the significant results of these discussions and presentations to document the need for and participatory interest in collaborative research critical to increasing and sustaining maize production worldwide, and to establish a jointly supported reference base for proceeding with these efforts.

The conferees did identify and present numerous specific problems in maize breeding, the control of diseases, insects and pests, stress tolerance, technology transfer, economics and sociology of production, farming systems, and related areas where collaborative research could significantly contribute to solutions. A selected list of priority problem areas considered amenable to collaborative effort and with potential for high payoff in the near-term is given at the end of this summary.

Participants were unanimous in establishing an ad hoc work group to pursue their several recommendations and charged this group to (1) identify a few selected collaborative activities which could be conducted and supported during 1985-86, and (2) evolve a long-term program of collaborative research, including an appropriate organizational structure and the identification of budgetary resources, involving CIMMYT, U.S. university and developing country maize scientists in problem areas of mutual interest and benefit.

The conferees complimented and commended CIMMYT for numerous maize program initiatives and achievements including:

- Development and improvement of many gene pools for the tropics, sub-tropics and temperate regions.
- Improvement of populations through recurrent selection and international testing, and their wide distribution for varietal development.
- Development and maintenance of unique genetic and breeding materials which are valuable resources to many scientists.
- Improvement of nutritional quality.
- Development of a breeding strategy to provide for utilization of high quality protein germplasm and a utilization model for effective consumption.
- Reducing losses due to environmental and other stress factors in the absence of basic knowledge about the control mechanisms.
- Significant contributions to national on-farm research programs through training and outreach efforts.
- Training national maize program workers, particularly at the mid-professional level.

The conference recognized that CIMMYT has an applied research orientation and a small staff of scientists with finite resources. Consequently CIMMYT must choose "priorities" and "targets of opportunity" for research very carefully including those for collaborative research in more basic areas. The comparative advantages which CIMMYT can offer through collaborative efforts, such as an integrated world-wide testing program and access to extensive germplasm resources, are very desirable as a necessary complement to more basically oriented programs for evaluating breeding methodologies and procedures, agronomic practices, and production strategies. Similarly, comparative advantages of U.S. research institutions in the basic sciences and disciplines were recognized for their value in resolving problems related to applied and commodity production research.

CIMMYT is supportive of and has much interest in collaborative basic research with U.S. universities in support of maize improvement. Through this mechanism CIMMYT can tap the vast scientific resources at U.S. universities and have a window to new developments in biotechnology, physiology, etc., which could lead the way for incorporation of new technology into their applied and adaptive research. Similarly, access to CIMMYT's unique maize genetic and breeding materials, extensive international testing network, and selection data are resources of great interest to many maize scientists in the United States.

Principles considered essential to cost-effective collaborative research were emphasized throughout the conference. Central to these are 1) a common, sharply defined focus, 2) unique contributions through respective comparative advantages, 3) a minimal administrative mechanism, and 4) support to provide "network linkages" necessary to utilize the internal resources of cooperating units.

The panel on organization and structure emphasized a need for selective priorities in the real world of scarce resources, and the necessity to capitalize upon the internal comparative advantages and resources available to our institutions. Full support for a collaborative maize research program was discouraged. However, support to provide for network linkage and communications was stressed as critical to the development and management of a minimal system necessary to organize and maintain a collaborative working mode among maize scientists at CIMMYT, in the United States and in developing country programs. This mechanism is referred to as a "mini-CRSP" by some scientists because of association with current Collaborative Research Support Programs.

Training of professionals and scientists was emphasized throughout discussions and in the reports. The need to staff developing country programs with maize workers oriented to their local program needs can be best accomplished through advanced training in the U.S. with appropriate research at CIMMYT, or with CIMMYT support in home country programs. Concurrently the potential to accomplish significant research through such cooperative training programs should be utilized in the interest of both time and scarce resources in these countries.

Following are key examples of the many areas identified and recommended for collaborative research. The conference did not attempt to prioritize these for either near-term or high-payoff potentials.

Recommendations for Collaborative Research

- Facilitate the development of improved seed production in targeted countries.
- Address questions of maize collection, regeneration and evaluation as related to expressed concerns of gene loss and genetic drift.
- Assess and evaluate the use of wide crosses as a source of specific characteristics having agronomic importance.
- Formulate applicable procedures and evaluate CIMMYT gene pools and populations.
- Identify effective procedures for inbred-hybrid utilization in support of national programs.
- Address more directly CIMMYT's program needs including utilization of CIMMYT materials in development and application of molecular approaches for maize improvement.
- Review application of "state-of-the-art" genetic engineering for LDC utilization.
- Develop an overall collaboration strategy and models for nutritional interventions which include QPM as a major component.
- Plan and implement research on biological mechanisms controlling stress tolerances.
- Apply recently developed virus identification techniques to the control of unidentified virus strains for developing resistance and limiting their dissemination, e.g., East African programs.
- Adapt current crop-loss methods for on-farm identification and estimation of economic consequences of production constraints.
- Develop practical methods and models for analysis of data, feedback to researchers, and development of recommendations from on-farm trials.

ACKNOWLEDGEMENT

We greatly appreciate the cooperation and assistance of the International Agricultural Programs staff of the University of Minnesota which was instrumental in the planning and organization for this conference. Thanks are especially due to Helen Cullen, Audrey Engebretson, Julie Borris, Phay Vang and Lucy Shrader for their able staff support throughout the planning, arrangements, and Proceedings preparation; and to Joan Darrell for her expert editorial assistance in preparation of these Proceedings.

We are very grateful to the entire CIMMYT Conference and Visitors staff so ably directed by Linda Ainsworth for their efficient and hospitable arrangements which contributed immensely to the success of this program.

Special acknowledgement is due Dr. Delane Welsch, Assistant Dean for International Agricultural Programs, for his personal assistance in planning and overall program support; and to Dr. Malcolm Purvis, formerly Assistant Dean for International Agricultural Programs at the University of Minnesota, for his personal encouragement and support during the early planning for this conference.

The success of the conference would not have been possible without the inter-active participation of all the conferees, for which we are most grateful. We are especially indebted to the CIMMYT staff who reviewed their programs for the conference, and to those conferees who willingly accepted group leadership roles for the discussions, gave presentations and prepared summaries.

This conference would not have been possible without the material support provided by our sponsors: The United States Agency for International Development¹, Bureau for Science and Technology Agriculture Office; The International Maize and Wheat Improvement Center, Maize Improvement Program; and the University of Minnesota International Agricultural Programs. We hope the success of the conference sufficiently rewards their trust in granting this support.

¹ U.S.AID Grant No. DAN-1406-G-SS-3053-00

A LIFELINE TO THE DEVELOPING WORLD:
MORE AND BETTER MAIZE THROUGH COLLABORATION

Nyle C. Brady*

INTRODUCTION

I am very pleased to be here this morning to participate in this important occasion and to contribute some thoughts on what promises to be a very useful and worthwhile collaboration.

You should all be commended for pinpointing one of the important research gaps -- the need to focus more attention on maize breeding and production in the tropics and subtropics -- and for envisioning a practical international research network to fill that gap. CIMMYT and the University of Minnesota deserve recognition for assembling this prestigious group of scientists from national and international organizations from both developing and more-developed nations around the world.

I am especially pleased that U.S. universities are participating in this effort and that they are willing to bring their significant expertise to bear on these developing-country problems. Along with CIMMYT and the other participants in this conference, they constitute a lifeline to the developing world. The U.S. Agency for International Development is pleased to help support this important effort.

This kind of conference is an excellent forum for exploring vital research issues and for setting realistic directions and goals. It is an opportunity to exchange, compare and evaluate the relative merits of new ideas. In this forum, recent advances in maize improvement made by CIMMYT and its collaborators in developing countries can be reviewed along with similar progress made by U.S. and other developed-country scientists. We are hoping that these reviews will help stimulate collaborative interaction on the common focus of maize improvement.

MEN OF VISION

As we meet here today, credit should be given to men of vision who created the institutions we represent. Some of these farsighted leaders created the Land-Grant University system in the United States, along with its associated state experiment stations and cooperative extension services. Working with the U.S. Department of Agriculture, these universities developed a most impressive system of gaining and promptly disseminating new knowledge.

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Furthermore, that system assured that the focus was on the problems facing U.S. agriculture, and not just on science for science's sake. Lastly, the system was efficiently coupled with the private sector which assured the rapid adoption of new technology as it emerged. In no small part, this system underpins the world's greatest agricultural factory which has consistently helped the world weather its food crises.

Another group of visionaries turned their attention to international agricultural research with a sharp focus on problems of the developing nations. They created a truly unique network of international agricultural research centers (IARCs) and associated cooperators in the developing nations. Our host for this conference, the International Center for Maize and Wheat Improvement (CIMMYT), not only typifies the IARCs but has provided much of the conceptual basis for the entire system. The forward-looking intellectual giants who created CIMMYT and the other 12 international centers deserve our commendation and gratitude. They developed an unparalleled system of inter-donor coordination, and of monitoring and support for these centers.

AGRICULTURE'S SUCCESSES/CHALLENGES

The agricultural research complex, which we represent, has had amazing successes in the past two decades. It has helped the world avert the widespread famines which were predicted in the early sixties. During a period of unparalleled population growth, per capita food production world-wide has actually increased slightly in the past two decades. A recent analysis by Prosterman¹ flatly states that "hunger-related deaths in the world are declining."

But widespread hunger still exists, and in some countries of the world, notably those in Africa south of the Sahara, per capita food production has declined. While their overall food production increased at a rate of about 1.5% in the 1960s and 1970s, their average population increase was 2.9%. Commercial food grain imports increased to 20 million tons in 1980 and food aid reached 1.5 million tons. While droughts may be partly responsible for this situation, much of it is due to inefficiency of food production, including inadequate production technologies which agricultural research can help improve.

The situation in Africa reminds us that past successes do not necessarily assure future successes. In the first place the population explosion of the past few decades continues unabated in some countries. This problem is the primary focus of the second World Population Conference underway in Mexico City this week.

The participants will grapple with some rather shocking population projections. According to a recent World Bank report², the world's

¹Prosterman, R. L. The decline in Hunger-Related Deaths, The Hunger Project Papers No. 1, May 1984, The Hunger Project, San Francisco, Calif.

²1984 World Development Report, World Bank

population, which currently stands at 4.8 billion, is expected to increase to more than 10 billion by the middle of the next century. Furthermore, most of this increase will occur in the developing countries, which are already struggling to meet their current food demands. The tropical and subtropical areas will be most seriously pressed.

Africa, with its drought-prone areas, is especially vulnerable, not only because of the serious agro-climatic constraints but because of the unavailability of sufficient improved technologies. The green revolution has yet to make significant impacts in Africa where water and fertilizer inputs are limited. Furthermore, misguided public policies which favor the urban consumer at the expense of the farmer have not made it profitable for the farmer to adopt new technologies once they have been developed.

PROGRESS IN MAIZE PRODUCTION

Increased yields and production of wheat and rice are commonly credited with much of the success of the green revolution. But, in the last decade, the growth rate of maize production in developing countries has also been significant, being 3.7% compared to 4.7% for wheat. Furthermore, much of this increase was associated with improved maize varieties. In 1983, for example, an estimated 5 million hectares in developing countries were planted to varieties derived from germplasm from CIMMYT and its cooperators. These varieties included hybrids as well as synthetic varieties.

Between 1980 and 1983 alone, over 70 new varieties from the CIMMYT coordinated network, of which 25% are hybrids, were released in 22 developing countries. These varieties are adding about one million tons annually to worldwide maize production. Dramatic increases are widespread. In fact, maize is grown on a significant scale in more countries than any other crop. Fifty-seven developing nations are each producing more than 100 thousand hectares of these new varieties.

Collaborative work in Africa has produced significant results which are good signs for the future. Kenya's progress is an example of the potential for growth. In 1963, no improved maize varieties were planted in that country. Through cooperative efforts, by 1980, 370 thousand hectares were planted to improved hybrid maize -- 94% of that cultivation was on small farms. Similar if somewhat less spectacular results have been noted in Zimbabwe where improved maize varieties have greatly increased national production levels.

Such dynamic improvements in maize production have, however, been limited. They have not generally been comparable to the improvements in irrigated wheat and rice that were part of the green revolution. It is time to overcome some of the still-existing barriers to greater production of maize in tropical and subtropical environments.

NETWORKING IN AGRICULTURAL RESEARCH

Most crop improvement programs, national or international, generally involve some kind of collaborative network. Certainly, networks characterized the relationship which existed among U. S. universities and the USDA during the early days of hybrid maize development in the United States. Likewise, each of the crop-oriented IARCs serve as coordinators of international cultivar testing and improvement programs. CIMMYT coordinates perhaps the largest such networks in its wheat and maize programs.

The network approach is also being encouraged in other research areas by U.S.AID and its cooperators. The Collaborative Research Support Program (CRSP) approach is being tried out in a number of subject areas. U. S. universities and their counterparts at selected sites overseas join forces to attack a high-priority problem of mutual interest. Although the CRSPs have been underway for too short a time to evaluate their long-term effectiveness, preliminary results are encouraging.

Several other U.S.AID supported networks are in place or are being contemplated. In just a few days I'll be helping to launch the International Benchmark Soils Network for Agrotechnology Transfer (IBSNAT) at the University of Hawaii. Using soil, crop, weather and management minimum data sets, the network will develop crop-performance prediction models and test their validity.

IBSNAT's major goal will be to accelerate the flow, maximize the success, reduce the failure and assess the long-term effects of agrotechnology transfer. These are the same goals you will have with regard to maize. Since CIMMYT also has state-of-the-art computer capability, IBSNAT's methods and progress may become of great interest to you.

Another project aimed at coordinating a research network is the Farming Systems Support Project being implemented by the University of Florida and cooperating universities. It addressed the needs of small-scale farmers in a number of African countries. A major focus of this effort is to adapt improved technologies to socio-economic needs at each site. The project has the cooperation of host-country agencies and national and international research institutions.

The International Soybean Research Network, coordinated by the University of Illinois, is another evolving collaborative effort. The network's aim is to improve and increase the production and utilization of this important legume.

The Water Management Synthesis project in Asia has some elements of networking. A consortium of U. S. universities provides technical back-stopping for national irrigation management programs, including those involving research. Likewise, a new collaborative Forestry/Fuelwood Research and Development network is being conceptualized for Asia. A similar, less formal network exists in Central America. There is considerable interest in exploring such networks in other subject areas such as dried beans, and sorghum and millet in Africa.

PRINCIPLES OF NETWORKING

Several types of international agricultural research networks are in existence. They vary from those limited to information exchange to those which are relatively complex collaborative research efforts collectively planned and implemented by researchers throughout the world. While each type has its merits, from my own observations, those which require significant intellectual as well as programmatic inputs by all participants are most successful. The following are among the criteria which tend to characterize successful networks:

1. There must be a sharply-defined common focus which transcends national and disciplinary boundaries. Successful networks cannot be all things to all participants.
2. The network approach must provide some comparative advantage over the traditional independent research system. Only those activities should be included in a network which can be more efficiently and effectively handled within the network than through the traditional approach.
3. Developing country partners should be involved from the very beginning in conceptualizing and organizing the network. Too often, networks are set up by donors and/or developed-country institutions, and the developing-country scientists are asked to "join." Under these circumstances the LDC cooperators always have a perception that it is someone else's network they are asked to help implement.
4. Each cooperator (national or international) in the network must be able to make one or more unique contribution to the network's success. The contribution of each cooperator should be to the overall advantage of the other cooperators.
5. Each cooperator must invest some of its own resources (human as well as financial) to complement those from others in the network or from the outside. I know of no network with potential for sustained accomplishments where the cooperators are financed entirely from outside their regular budgetary channels. Networks set up merely to provide financial resources for the cooperators commonly fail.

OPPORTUNITIES FOR COOPERATION

It seems to me there are numerous opportunities for cooperation between CIMMYT and U. S. universities on maize improvement. CIMMYT already has a well-structured system in place in a number of developing countries. That system provides ongoing experience in developing, distributing and testing superior maize germplasm. Over the years, the Center has also accumulated much experience in training and in analyzing the test data.

Similarly, the U. S. universities have an outstanding agricultural-knowledge base and accomplishments that complement and interlock with CIMMYT's experience. These include broad expertise in education and training, vast experience with extension and delivery services, and tremendous demonstrated ability in fundamental agricultural research, and in farming systems research. They also have outstanding research

facilities and a strong research base in supporting disciplines such as biochemistry, molecular genetics, and biometry. As we move into the areas of tissue culture and more sophisticated genetic engineering approaches, the need for these scientific disciplines will expand.

SCIENTIFIC ISSUES

Each of you is much better qualified than I to identify the specific scientific issues which should be addressed at this conference. I do know that there are specific problems and clearly limited resources. The challenge for you, as researchers, is to identify and address the most pressing of these issues and come up with suggestions as to how they should be handled. A few such areas have been called to my attention:

One fundamental question involved diverging schools of thought on breeding strategies -- population improvement versus development of parental lines having a specific trait or character. While both strategies yield gains, we must explore the comparative advantage of each line of research to determine which holds the greater promise for solving a given problem.

Second, we need more effective ways to incorporate resistance to insect pests and diseases. An in-depth review is needed of the advantages of various screening methods. Some thought will likely be given to genetic engineering approaches which could be explored.

Third, the question of hybrids versus open pollinated varieties is still with us. Each of these strategies can be put to use in the various physical and technical environments of developing countries. I am sure you will continue to have an open dialogue on this issue.

Fourth, I would hope that some attention will be given to means of improving maize's tolerance of environmental stress. Included would be tolerance of drought, temperature extremes, and soil toxicities, especially excess acidity. Here again the possibilities of genetic engineering should be explored.

Fifth, is the question of wide crosses and factors affecting combinability. This is an area where the expertise of universities and CIMMYT can be complementary.

Sixth, there are a number of crop physiology questions that could be addressed. For example, plant nutrient efficiency in fertilization. I understand that nitrogen deficiency has been observed during grain filling even on well-fertilized CIMMYT plots. Reasons for this situation should be ascertained.

Beyond fundamental research questions, it is important that we not lose sight of important phases in technology transfer. One that is prominent in my mind is seed production. Another is longer-term conservation of genetic resources. You may also wish to give further thought to effective, long-term institution building that is not reactive to political and financial changes. It is clear that training will support and enhance all of these endeavors.

CONCLUSION

Given their complementary strengths, the growing resources of proven and promising program models and the tremendous concern we all have about world hunger, it is imperative that CIMMYT and the U.S. universities explore the future steps which should be taken to accelerate maize improvement. This lifeline, which each of you can provide to developing countries, should be extended and strengthened.

In making plans for future cooperation, I hope you will involve, at the outset, scientists from the developing countries with whom we are all charged to cooperate. They should be full partners in any kind of refocused and/or expanded collaboration. Within U.S.AID, we can support collaboration only if these national researchers are thoroughly involved since it is through our country Missions that our primary financial support is being channeled.

Lastly, may I say how important it is for participants in a collaborative program to utilize their respective comparative advantages. CIMMYT is best suited to handle long-term, field-oriented networks. Universities are ideally suited to do more basic research and combine this research with the training of scientists. Complementarity, not competition, should be arrived at through these two general areas of expertise.

Thank you for inviting me to share in the inauguration of your efforts. I will certainly keep an eye on your progress.

PROGRAM DISCUSSION PROCEDURES

James C. Sentz

The organization of this conference is based largely upon the consequences of several meetings following the implementation of Title XII legislation and presentation of the Collaborative Research Support Program concept. The program is structured so that individual and corporate contributions are not only important, but critical in determining the results and conclusions of our deliberations. The following are guidelines for discussion group organization and summaries.

- Group and Rappateur Assignments have been distributed. These group assignments are for the entire conference. Should you wish to make a change, however, please contact your topic chairperson.
- Moderators are to be named by each group at the start of each session. They are expected to guide discussion on the issues and allow equal expression from all discussants. We suggest that you establish an agenda early in each session to utilize your time effectively.
- Rappateurs are responsible for recording relevant material presented, and in consultation with the moderator prepare a summary report of deliberations. This will be presented orally to the workshop assembly and in writing for the chairperson and Proceedings. Report sessions will be recorded to facilitate preparation of your written copy as necessary.
- Issues are listed for discussion groups to consider first in each session, and then other relevant issues can be discussed. Issues are assigned in paired sequence as Group A - Issue 1, Group B - Issue 2, and so on.
- Chairpersons will integrate group deliberations into comprehensive Topic Reports. You may choose to further discuss topic issues with disciplinary representatives and/or others in this process. Reports will be summarized orally to the workshop assembly on Thursday and in writing for the Proceedings.
- "State-of-the-Art" knowledge among participants is assumed by the conference organizers. Discussions, therefore, should focus primarily upon the comparative advantages of universities, CIMMYT and developing countries for further technology generation and transfer (research, training and adoption), and associated problems.

I. GERMPLASM PRESERVATION AND GENETIC ENGINEERING
TECHNIQUES IN MAIZE IMPROVEMENT

ISSUES

- * Evaluation and Screening Techniques, Incorporation of New Introductions, Regeneration Procedures, Long Term Storage, and Distribution Protocol.
- * Inter-generic and Other Wide Crosses for Transferring Genetic Variability.
- * Which Aspects of Maize Improvement, Such as Nutritional Quality, Stress Tolerance, Gene Transfer, etc., Are Amenable to Genetic Engineering Techniques?
- * Are There New Traits to Explore and Develop Because Genetic Engineering Techniques are Available?
- * How Should New Bio-genetic Techniques be Integrated Into the Current Improvement Program, and What Will be the Position and Role of CIMMYT and Universities Toward Basic and Applied Research?

OVERVIEW OF THE CIMMYT GERMLASM PRESERVATION
AND WIDE CROSSES PROGRAM

David C. Jewell*

Maize Germplasm Bank

The CIMMYT maize germplasm bank comprises over 10,200 accessions, regenerated (using a modified half-sib system) from original collections. This material is currently in medium term storage (20-25 years). Long term storage facilities will also be available at CIMMYT by the end of 1984.

A data base for the bank is being developed, and trials are in progress to determine those traits which are most indicative of adaptation prior to evaluation.

The policies, plans, and use of the CIMMYT germplasm bank are discussed.

Wide Crosses

A "wide cross" in the CIMMYT maize program is defined as a cross with an alien genera to transfer useful genes for improving maize. Current emphasis is on crosses with Tripsacum and the resulting progeny. Our interest is primarily in introducing traits for which there is little or no known variability in maize. Over 130 F₂ hybrids are being maintained and the second backcross progeny have only recently been produced.

Tripsacoid maize from the United States is being converted to subtropical and tropical adaptation and a part of this material is in the fourth cycle of selection for southwestern corn borer resistance.

Several new techniques, such as DNA transformation using a pollen vector, are being investigated for their potential to speed up the process of introducing genes from an alien species.

Several techniques to permit the use of traits not accessible to the maize breeder are also being evaluated.

This work is being done at CIMMYT in collaboration with other institutions.

* CIMMYT International Staff, Wide Crosses Unit, Mexico

PANEL DISCUSSIONS and RECOMMENDATIONS

Ronald L. Phillips*

On the first day of this conference, Nyle Brady presented several principles for effective collaboration. These include: 1) a common, sharply defined focus; 2) apparent comparative advantages for each collaborator; 3) developing country partners to be included from the beginning; 4) expectation of unique contributions by each collaborator; and 5) an understanding that each collaborator is responsible for the necessary human and financial resources of their effort. We endorse these principles, and though not specifically addressed in each topic, they are incorporated into all planning for collaboration.

Germlasm preservation and genetic engineering techniques are fundamentally basic research area applications. These techniques represent an area with emphasis on genetics, cytogenetics and molecular biology. Their inclusion provides CIMMYT a window on new developments in genetics and should lead the way for incorporation of biotechnology into appropriate aspects of CIMMYT's programs. Through these areas CIMMYT can tap vast scientific resources at U.S. universities. The unique genetic and breeding materials that CIMMYT has developed represent valuable resources that are of interest to many U.S. university scientists.

There are many U.S. maize geneticists affiliated with U.S. institutions which do not have maize breeding programs. These scientists have had little opportunity to collaborate with CIMMYT maize breeders and, in addition, lack adequate facilities to train students from developing countries in maize genetics. A working relationship between these institutions and CIMMYT would be highly desirable. We also recommend that graduate training programs provide developing country maize breeding students exposure to molecular and cellular genetic information and techniques.

Our discussions are sub-divided into three topics: a) Gene Bank, b) Wide Crosses, and c) Genetic Engineering. Many areas are identified for direct collaboration between CIMMYT and U.S. universities. The following list of opportunities is presented in a logical sequence and the order does not reflect priorities. It is recognized that CIMMYT already has collaborative affiliations in many of these areas, but expanded collaboration is encouraged.

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A. Gene Bank

1. A lead institution should be agreed upon by the international community interested in preserving maize germplasm. If it is agreed that CIMMYT should take more than a passive gene bank role (i.e., store seed and use minimal descriptors), then U.S. scientists, CIMMYT, and others should form a consortium to define specific roles and obtain funds for these activities.
2. CIMMYT is now summarizing (computerizing) information on each accession in the gene bank. This summary, retrieval mechanisms based on descriptors, and communication of information could be considerably enhanced through collaboration with U.S. universities and national programs. When CIMMYT provides seed to cooperators, the recipient should be required to return information concerning that seed. Incorporation of information on collections held by other institutions would be most useful and desirable.
3. Collection of additional maize germplasm, with a few exceptions, can be accomplished through informal collaboration without major funding. Discussions with U.S. and other scientists should reveal areas of the world to be sampled for their maize variability (e.g., Himalayas, regions of Africa). National programs could make some collections with minimal effort. U.S. university projects in targeted countries could include germplasm collection in their priorities. Teosinte should be included in these collections.
4. Long-term storage should be a collaborative endeavor involving multiple locations and institutions. There should be follow-up evaluation on the CIMMYT-USDA Ft. Collins program so that previously submitted materials are adequately catalogued and handled.
5. Regeneration of gene bank accessions should continue to receive high priority. The USDA has funds for collaboration and expansion of this activity. Agreement should be reached by a representative group of concerned scientists on regeneration procedures to effectively maintain gene frequencies. Maintenance of original accessions versus pools or sets of accessions should be evaluated as an economic alternative. Collaborators could assess gene frequencies (using isozyme techniques, etc.) before and after regeneration to validate alternative procedures.
6. Collaborative effort could be effectively utilized to convert some day-length sensitive gene bank material to day-length insensitivity. This would allow greater distribution and utilization of these materials.
7. There is potential for extensive collaboration of other institutions with CIMMYT and the need to further evaluate individual collections held by CIMMYT. Economic traits should

include adaptation, resistance to major diseases and insects, and tolerance to striga, drought, heat, cold and acid soils. Collaborators should be identified to screen gene bank materials for laboratory characters.

B. Wide Crosses

1. Accumulation of appropriate genetic materials for wide crosses - Tripsacum, Sorghum, Zea diploperennis, teosinte, and others - could involve a significant collaboration with several U.S. scientists. Since the gene bank already represents a tremendous amount of variation, it seems prudent to continue the use of CIMMYT wide crosses for traits not likely to be found in existing maize stocks. Collaboration with U.S. scientists could be effective in discovering traits unique to Tripsacum that would be of practical value.
2. Successful recovery of wide-cross hybrid embryos offers many possibilities for collaboration. Many U.S. experts interested in embryo rescue, ovule culture, tissue culture and related technologies would welcome the opportunity to collaborate with CIMMYT.
3. The assumption is made that CIMMYT does not have sufficient resources to completely analyze cytologically all wide crosses and later generation progenies. U.S. cytogeneticists could be involved with these analyses in either U.S. or CIMMYT laboratories to greatly expand the information available from this material.
4. Discussants were pleased to learn that wide-cross material is being evaluated for southwestern corn borer resistance. Other scientists would be interested in screening for additional traits if CIMMYT could produce sufficient materials.

C. Genetic Engineering

1. Collaboration between U.S. and CIMMYT scientists in the area of genetic engineering could best be stimulated by a conference at CIMMYT to familiarize U.S. maize scientists interested in cellular and molecular approaches with CIMMYT's objectives, programs, facilities, and needs. CIMMYT might identify genetic materials (strains) to be used in such studies and the assembled group could identify traits of interest which might be amenable to genetic engineering methods.
2. CIMMYT and appropriate U.S. institutions or scientists could investigate funding of biotechnological research on maize. For example, the Rockefeller Foundation is instituting a new funding program on plant molecular biology, not including maize. Could the Foundation's decision to exclude maize be changed? Are there other funding sources willing to support and facilitate development of biotechnology involving CIMMYT?

3. The occurrence of spontaneous mutations in cell and tissue cultures provides potential for recovering certain traits of interest in CIMMYT's genetic materials. Selection for specific traits probably would be of greater usefulness than screening random variation.
4. Development of good tissue culture regeneration systems with CIMMYT's genetic stocks would be of interest to several U.S. scientists. CIMMYT scientists should spend time in U.S. laboratories to learn new tissue culture methods.
5. Methods to select tissue culture for specific traits could be effectively developed by collaborative efforts. For example, CIMMYT might stimulate research isolating toxins from disease pathogens for use in tissue culture selection programs using genetic materials in their breeding programs. Other examples include selection for protein quality mutants (e.g., use of amino acid analogues, or the lysine and threonine screening technique) and aluminum toxicity tolerance.
6. Chromosome breakage is a relatively common occurrence in maize-tissue cultures. Would it be advantageous to tissue culture an F_1 between maize and Tripsacum and allow chromosome recombination (i.e. translocations) to occur? Comparisons of regenerated plants and their progenies with materials derived by sexual crosses could be an interesting and potentially useful project for a collaborative effort. The F_1 of maize and Zea diploperennis grows well in tissue culture, and plants can be regenerated. How would tissue culture derived materials of this hybrid, which has good chromosome pairing, compare with sexually derived materials?
7. Genetic engineering technology affords the potential of developing molecular diagnostic tests for the presence of viruses or viroids. Such diagnostics may be particularly useful to CIMMYT and national programs in assessing the level of virus infection for quarantine purposes. A molecular diagnostic test could prove the material to be virus free. Several U.S. molecular biologists have the expertise to develop molecular probes to identify certain viruses.
8. Certain molecular probes could be developed to assist in identifying Tripsacum or maize chromosomes in the materials being generated in the wide cross program. In situ hybridization (i.e. direct nucleic acid hybridization to the chromosomes) or various analyses on isolated DNA would be applicable. Collaboration could involve U.S. molecular biologists, cytogeneticists, etc.
9. Tests of the DNA transformation efficacy could involve the use of a cloned molecular probe, such as those used for the waxy or shrunken or Adh gene. For example, maize plants homozygous for an appropriate waxy allele could be pollinated with its own pollen that had been exposed to wild-type DNA. Phenotypic detection could include the pollen phenotype. The probe could be used to show presence of wild-type DNA. An even better system might involve

using an Adh probe with homozygous recessive Adh and screening for anaerobic growth of the initial seedlings. Several approaches could be used in collaboration with different U.S. universities.

10. The QPM program offers a wealth of material of interest to U.S. scientists. What has happened that allows a homozygous opaque-2 genotype to possess hard endosperm? Are there certain zein genes now expressed which are not expressed in opaque-2? Collaboration with U.S. maize molecular geneticists might provide valuable information useful in making future breeding decisions.
11. CIMMYT might also encourage genetic and molecular genetic research on gametophyte factors useful in providing isolation in their QPM material.
12. CIMMYT and many U.S. universities have great facility for and proven expertise in evaluation of genetic materials. All of the possible cell and tissue culture and molecular biology methods ultimately require evaluation and, most likely, further breeding. CIMMYT is uniquely qualified to evaluate such materials especially when CIMMYT materials are used in research.

II. BROAD BASE GENE POOLS FOR MAJOR WORLD
PRODUCTION AREAS

ISSUES

- * Pragmatic Definition of World Environments and Genetic Characterization for Generating Basic Gene Pools.
- * Utilization of Gene Pools in International and LDC National Programs and Alternative Procedures for Maintaining and Distributing Genetic Materials.
- * Procedures for and Problems Associated With Incorporating Germplasm Bank Materials Into Gene Pools.
- * LDC National Program Needs and Role in Gene Pool Maintenance.
- * Basic Research Needed and Role of Developed Countries in Gene Pool Maintenance.

THE CIMMYT MAIZE BACK-UP UNIT

Hugo S. Cordova*

The back-up unit of the CIMMYT maize program serves as a support unit to provide superior genotypes or families to the advanced unit on a continuous basis so that (1) improvements in advanced populations can be obtained from cycle to cycle and (2) the reduction of genetic variability can be minimized.

The objective of the back-up unit is to develop and improve maize gene pools with broad genetic base for major maize-growing areas worldwide. These gene pools are mass reservoirs of genes and have a broad genetic constitution. They are formed by genetic mixing of several diverse maize collections, varieties, variety crosses, and hybrids with similar climatic adaptation, maturity, grain color, and texture.

CIMMYT maize gene pools meet the climatic requirements of tropical highlands, tropical lowlands, and sub-tropical and temperate zones. Within each climatic area of adaptation, these gene pools are classified on the basis of maturity (early, intermediate, and late), grain color (white and yellow), and grain texture (flint, dent, floury). The back-up unit currently handles 33 gene pools: 9 for the tropical highlands, 12 for the tropical lowlands, 8 for subtropical areas, and 4 for temperate maize-growing area highlands.

A CIMMYT modified ear-to-row half-sib system is used for the improvement of the gene pools. Two cycles of recombination and selection are completed each year, except for the highland gene pools in which only one cycle of improvement is completed annually. Between 450-500 families constitute each gene pool. Promising accessions from the germplasm bank and superior introductions from national programs are regularly added to the corresponding pools to broaden their adaptation and to maintain a high level of genetic variability. Selection pressure among families is about 40 to 50 percent and within-family selection is 6 to 8 percent. S₁ recurrent selection is used every fourth cycle to eliminate undesirable traits from the gene pools and superimpose pressure for traits with low heritability. Priority selection traits considered in the improvement of the gene pools are yield, husk cover, maturity, plant and ear height, lodging, and resistance to diseases and insects. Depending upon their potential use at various locations, the pools are subjected to different stress pressures. These include: ear rots (fusarium roseum), stalk rots (f. moniliforme), corn borer (D. grandiosella), and fall armyworm (spodoptera frugiperda).

At the end of 1983, the tropical highland pools had undergone from 2 to 6 cycles of selection; tropical lowland pools, 13 to 19 cycles of selection; sub-tropical pools, 12 to 19 cycles of selection; and temperate pools, 11 to 13 cycles of selection.

* CIMMYT International Staff, Back-Up Unit, Mexico

Considerable progress in yield potential is being achieved in most of the CIMMYT maize gene pools, ranging from 1 to 6 percent gain per cycle in the lowland tropical pools and from 2 to 5 percent gain per cycle in the sub-tropical pools. Other traits, such as maturity, plant and ear height, and resistance to diseases have also improved during the process of selection.

PANEL DISCUSSIONS and RECOMMENDATIONS

Charles O. Gardner*

Broad base gene pools provide a valuable source of genetic diversity for use in national corn breeding programs worldwide, in developed nations as well as less developed ones. CIMMYT maize breeders have obviously devoted considerable time and effort and have achieved excellent success in developing and improving many broad base gene pools for the tropical and subtropical areas, and more recently have developed pools for temperate maize regions. Certainly they are to be commended for their efforts. Collaborative research is suggested in the following areas.

1. We could all benefit from collaboration in developing a better classification system for the world maize growing environments. Scientists with expertise in plant physiology, climatology, entomology, plant pathology and geography should be involved along with agronomists. If environments could be more clearly defined and classified, it would increase the efficiency of CIMMYT's worldwide testing programs and greatly benefit LDC national programs.
2. The accumulated data in CIMMYT's files for yield trials conducted over the past 10 years represent a rich reservoir of useful information on genotypes, environments, and genotype x environment interaction. Further collaborative analyses and evaluation of these data could be very productive for better understanding these pools and populations and the environments in which they are grown. Unique genotype x environment interactions could be extremely valuable in characterizing particular genotypes and particular environments.

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3. Further studies of the stability analyses including response curves as well as their b values should prove worthwhile. The ideal which we seek is a population that produces relatively high yields in poor environments and also responds to more favorable environments. Such a response might well be curvilinear.
4. Collaborative efforts to more clearly define environments, genotypes, and genotype x environment interactions, and a greater knowledge of germplasm bank components would foster collaborative efforts toward more efficient development of new gene pools for specific environmental situations.
5. Enhanced characterization and improvement of the back-up gene pools through more efficient screening for environmental and biological stress tolerances has considerable potential. U.S. universities could collaborate with CIMMYT in the basic research for understanding various stress tolerances and in developing more efficient screening techniques for use in these selection programs.
6. Collaboration in the establishment of new gene pools where the contribution of each component and its particular characteristics including isozyme patterns are known would provide an excellent opportunity to monitor changes that occur in a selection program over time. Physiologists, plant pathologists, and entomologists should be involved along with plant breeders.
7. At present, we know relatively little about the genetic structure of populations and the changes that are occurring under directed selection for specific traits. Selection for tolerance to various physiological and biological stresses with some emphasis on yield seem appropriate in such a population.
8. There are many ways for forming and maintaining gene pools. Further study of the methods used for forming, maintaining, and improving gene pools would be of considerable benefit to corn breeders worldwide. Consideration must be given to many factors including the number of accessions, mating system to form the initial population, generations of synthesis required to break linkages prior to initiating selection, the breeding system employed, recombination of selected entities, and effective population size. The procedures used must ensure that desirable alleles are maintained at desirable frequencies in the population. Collaboration among U.S. and CIMMYT scientists would provide comparative advantages and mutual benefits.
9. Collaborative efforts in assaying current back-up populations would also make them more useful germplasm reservoirs for the improvement of specific traits in LDCs. Many universities are uniquely equipped to screen for one or more disease organisms or insect biotypes. Mini-reservoirs might also be developed in order to achieve a high level of resistance to a specific trait before being fed back into the main gene pool or used directly in breeding programs.
10. Although it seems logical to maintain separate yellow and white seeded pools, collaborative studies should be conducted to study the

consequences of merging similar kernel type pools. Detailed studies of the original and merged pools, including isozyme patterns, would permit the monitoring of changes that might occur over time. Following several generations of selection, white and yellow seeded fractions could be extracted for comparison.

11. Procedures for merging germplasm accessions into ongoing germplasm pools should be studied more extensively. Collaborative evaluation of techniques to accomplish such mergers would objectively establish sound procedures. If such a merger is to incorporate a specific gene or set of genes, we should be able to calculate the probability of its loss using current practices.

12. LDC program needs for back-up gene pools is obvious. While the currently available pools generally meet these needs, the development of pools with a high level of resistance to major disease and insect problems, such as corn earworm, fall armyworm and maize streak virus, would be extremely useful to CIMMYT and LDCs. There is considerable potential for productive collaboration among U.S. and CIMMYT scientists in this area.

13. The identification and maintenance of heterotic patterns in establishing gene pools deserves considerable attention. Most commercial hybrid corn seed companies separate germplasm pools in such a way as to maximize heterosis in hybrids between lines from opposing pools, yet materials have been identified that combine equally well with both such pools. Collaborative effort among U.S. and CIMMYT scientists could prove mutually productive in this area.

14. U.S. universities are well equipped to train scientists in population genetics, quantitative genetics, plant breeding and related areas concerned with germplasm improvement and management issues. CIMMYT has contacts throughout the world and can recommend qualified students for training. A collaborative effort with some financial assistance in the form of Graduate Assistantships would permit expanded training of LDC scientists.

III. DEVELOPMENT AND IMPROVEMENT BY RECURRENT SELECTION OF
POPULATIONS DERIVED FROM GENE POOLS

ISSUES

- * Recurrent Selection Technology and Application for Developing Improved Populations Including International Progeny Testing.
- * Role and Use of Inbreeding as a Tool for Pyramiding Favorable Genes for Yield and Agronomic Characteristics, Disease and Insect Resistance and Other Stress Tolerance.
- * Breeding Procedures and Techniques for Disease and Insect Tolerance/Resistance.
- * Improvement and Utilization Alternatives Within LDC National Programs.
- * Improved Populations vs. Line and Population Hybrids, and Seed Production for LDC Production Programs.

THE CIMMYT MAIZE ADVANCED UNIT

Shivaji Pandey*

The advanced unit develops needed maize populations using superior fraction of appropriate gene pools and other materials and improves them through International Progeny Testing Trials (IPTT). This unit presently handles 23 populations, 15 with lowland tropical adaptation and 8 with adaptation to subtropical and mid-altitude tropical conditions. These 23 populations are divided into two groups of 12 and 11 and each group is evaluated in the IPTT in alternate years.

The population improvement procedure involves: a) evaluation of 250 full-sib families making up a population along with 6 local checks in a simple lattice design at 6 locations internationally; b) bulk recombination among the S_1 families from approximately 50 selected full-sibs, and c) reciprocal plant to plant crosses among the half-sib families. Although every population is improved for most agronomic traits, it is improved for one or two primary traits specifically in the selfing and bulk-sibbing cycles. The primary trait(s) for a given population is that which would increase the value of the population in the areas of its adaptation in the immediate future. Superior germplasm is systematically introduced into the populations from their corresponding gene pools every cycle of selection to maintain genetic variability.

At every site where an IPTT is planted, 6 to 10 superior full-sibs are selected visually and on the basis of data, and recombined to form site-specific experimental varieties. These varieties are identified by the name of the location and four digits. The first two digits indicate the year of test and the last two digits indicate the population number (e.g. Pirsabak 7930). Recombination among the 6 - 10 full-sib families that performed well over all locations where a population was tested results in an 'across' variety. These varieties are evaluated using their second generation seed in Experimental Variety Trials (EVTs) at approximately 50 sites world-wide. High yielding and stable varieties are identified based on the EVT data and further evaluated in Elite Variety Trials (ELVTs) at more than 50 sites.

As a result of this selection the populations have been improved for most agronomic traits under varying environmental conditions, but their performance has particularly improved under low yielding and stress environments. Recent derivatives from a given population are higher yielding and more stable than those derived in earlier cycles. Each cycle of improvement in the populations provides varieties that are about 4% higher in yield. In general, there is no evidence of reduction in genetic variability as a result of selection.

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CIMMYT materials are extensively used by both national programs and the private sector. Approximately 125 releases have been made in 30 countries using CIMMYT materials - 77% in the form of varieties and 23% in hybrid combinations. Although both 'site-specific' and 'across' varieties have been released, the latter are slightly favored. In 75% of country variety releases, the variety was developed on the basis of data from another country. Approximately 8% of the maize growing area in the developing countries is planted to CIMMYT derived varieties. Their yield contribution is estimated at 600,000 tons annually and worth 90 million dollars at current international maize prices.

PANEL DISCUSSIONS AND RECOMMENDATIONS

Arnel R. Hallauer*

Success in plant breeding requires useful sources of germplasm. After promising sources of germplasm have been identified, it is necessary that breeding methods be imposed that will improve quantitatively inherited traits in a systematic manner. Recurrent selection methods were developed to meet this objective.

Genetically broad base pools were developed at CIMMYT. The next logical step was to conduct recurrent selection to improve the pools to make them more useful to maize breeders. Regardless of the criticisms that may be directed at formation of the pools and the selection methods used to improve the pools, the CIMMYT maize breeders must be commended for taking initiative in the formation of these pools, initiating selection programs in improving their usefulness, and providing improved germplasm to maize breeders throughout the world. In the developed maize production areas of the world, there is concern about genetic vulnerability. The pools and populations developed by CIMMYT provide valuable back-up sources of germplasm to meet future demands.

There are major material benefits to be realized for both U.S. universities and CIMMYT to collaborate in population improvement research studies. The potential for increasing knowledge about effective and efficient population improvement exceeds that which could be achieved separately and will benefit maize breeders and their clients worldwide. The following recommendations for collaboratative study were discussed.

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1. Analyses of selection response to determine differences among CIMMYT populations, their genetic structure, how they respond to selection relative to the use of closed or open-ended populations, and development and testing of selection indices that would be appropriate for the selection methods used. These studies would be of interest to CIMMYT to measure the relative effectiveness of their selection methods, and to U.S. university scientists because this type of information is not generally available to them. These studies would provide guidelines for future research planning.
2. Theoretical and empirical studies to determine the most effective breeding methods for accumulating genes in multiple-trait selection. Is the use of inbred progenies more, or less, effective than the use of non-inbred progenies? What is the importance of modifier gene complexes relative to major genes, and how can they be effectively manipulated? These problems occur in all breeding programs. The information would be mutually beneficial to all breeders because multiple-trait selection is important in population improvement as a foundation for breeding programs.
3. Study of the basic genetics and ecology of tropical pests; develop mass rearing techniques to provide repeatable levels of infection and/or infestation in screening for pest resistance; conduct genetic resistance studies to improve host-plant resistance. These studies would be of immediate value to CIMMYT and LDCs. They would also provide insurance information for other areas where there is potential for the pest problem to develop. Effective screens are necessary if we are to upgrade the general level of pest resistance in our populations.
4. Good seed quality is mandatory in the improvement of maize production. Seed quality is under genetic control and can be improved by selection as efficient screening methods are developed. CIMMYT and U.S. universities can strengthen the technical knowledge of national program scientists in cultivar maintenance and seed production by continuing to conduct or initiate training programs as requested by LDCs. Research training centers and education curricula are available in some U.S. universities to train people to know the characteristics of good seed quality. CIMMYT and the U.S. universities should collaborate to generate a scientific base of knowledge to improve the technical evaluation and screening mechanisms necessary for good seed quality. This information would be useful for increasing maize production worldwide.
5. Train research scientists in plant breeding and germplasm improvement methodologies to develop cultivars that can be used in different areas of the world. CIMMYT and U.S. university scientists have responded to these needs, and they should continue. This is a unique opportunity for greater impact on LDCs by providing more opportunities for education and training. As U.S. university scientists become more aware of the problems and needs in LDCs they will be more responsive in training scientists for these countries.

IV. QUALITY PROTEIN MAIZE:
BREEDING, NUTRITIONAL ASPECTS AND ADOPTION

ISSUES

- * Methodology for Breeding Hard Endosperm Opaque-2 Grain.
- * Prospects and Problems in QPM Adoption.
- * Utilization of Quality Protein Maize.
- * Nutritional Aspects of Opaque-2 and Other Grain Types.
- * Seed and Production Problems Associated With QPM.

THE CIMMYT QUALITY PROTEIN MAIZE PROGRAM

Surinder K. Vasal*

CIMMYT has been actively engaged in the development and improvement of Quality Protein Maize (QPM) for the past 14 years. Although several mutants have been used to boost the levels of lysine and tryptophan of maize endosperm protein, the opaque-2 gene has been used most extensively in CIMMYT's QPM breeding program. Initially the thrust was on developing soft endosperm opaque-2 materials. These materials, however, failed to gain acceptance by farmers due to several crucial problems. There was general consensus among maize breeders that these materials had reduced yield, unacceptable kernel phenotype, greater vulnerability to ear rots and stored grain pests and a tendency to dry slowly following physiologic maturity of the grain.

In order to develop acceptable QPM materials, several new research ideas and approaches were explored and tried at CIMMYT. The approach that seemed most appropriate and that could result in acceptability of QPM materials was the accumulation and exploitation of genetic modifiers of the opaque-2 locus. Before this approach could be used there was a need to develop QPM donor stocks with modified endosperm. As this objective was achieved, a complete switch over in the breeding strategy was implemented. Using the donor stocks, a wide array of QPM germplasm was developed through a conversion program and through the formation of QPM gene pools. In addition to germplasm development, progress was reported in overcoming problems of yield, seed appearance, ear rots, and the drying down ability of QPM materials.

To make the best use of QPM germplasm, efforts have been made over the past several years to consolidate and reorganize the QPM germplasm. In the back-up stages, 8 tropical and 6 subtropical QPM pools are currently being handled. In addition 6 tropical and 4 subtropical advanced unit QPM populations have been formed and will be subjected to improvement through the international progeny testing system. Experimental data from international tests show superior performance of several QPM materials.

The objectives and progress of several exploratory research projects are presented. QPM materials are being adapted in some countries. The utilization and nutritional aspects of QPM programs are discussed briefly. There is renewed interest in QPM materials and the outlook for commercial utilization of these materials appears very promising in some countries.

*CIMMYT International Staff, Quality Improvement, Mexico

PANEL DISCUSSIONS AND RECOMMENDATIONS

David V. Glover*

The very nature and complexity of constraints to quality protein maize (QPM) production and utilization in developing countries suggests that approaches to improvement must involve totally integrated and multi-faceted breeding and nutritional strategies. It is recognized that CIMMYT has made a major effort to improve the nutritional and agronomic quality of maize. There has been considerable progress made through the use of modifier genes for homozygous opaque-2. The CIMMYT staff is to be commended for the development of breeding strategy which has brought us closer to providing quality protein materials that may eventually make their way into the market place.

Because of previous experiences with high-lysine materials, there is general skepticism surrounding quality protein materials and their ultimate utilization. It appears, then, very important that programs for the utilization of QPM should be viewed as part of a total nutritional strategy directed to specific countries or areas with specified target consumption, i.e., animal and/or human consumption. This approach could provide more definitive models for relative effectiveness of nutritional intervention strategy, establish trust, and gain acceptance among the scientific community and public administrators.

The summary of discussions is divided into three areas: A) Quality protein maize strategy, B) Breeding, genetics and production, and C) Utilization of QPM. Many items were identified for direct collaboration between CIMMYT, U.S. universities and LDCs. This presentation is intended as a logical summary of the discussion results, and research priorities should be established through further discussions. Some recommendations may be outside the CIMMYT mandate and therefore cannot be implemented.

A. Quality Protein Maize Strategy

1. Collaboration between U.S. university, CIMMYT and LDC scientists should be encouraged to develop a general strategy and model system to evaluate the ultimate usefulness of quality protein maize. There needs to be serious assessment of which LDCs to target, and also the major focus for ultimate utilization of QPM, (i.e. animals and/or human consumption) to realize the greatest impact from QPM.
2. The assumption is made that programs for production and utilization of QPM will require some sort of a seed industry. Once target LDCs are established, collaboration among U.S., CIMMYT and LDC scientists and seed industry related groups would help ensure a system of seed production which would encourage QPM adoption and utilization.

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3. Collaborative study of QPM models is recommended to determine relative effectiveness of nutritional intervention strategies which include QPM and/or normal maize in food blends or mixtures. This collaboration would best be served by key U.S. University and CIMMYT scientists from several disciplines interacting on this multi-faceted problem.

We recognize that there have been several studies on nutritional intervention with QPM. Further collaborative study seems appropriate as there exists confusion on the part of nutritionists as to the most limiting nutrients and the ultimate impact QPM may have on humans.

B. Breeding, Genetics and Production

Progress has been reported in overcoming problems of yield, seed appearance, ear rots and dry-down ability in QPM materials. And indeed the prospects for adoption of QPM in certain target areas look encouraging. However, there are some problem areas which need definitive answers before extended claims are made for QPM adoption. It is in answering these questions which concern QPM materials that mutual collaborative research can best serve to clarify and speed efforts to make acceptable QPM germplasm available for adoption.

1. Cooperative evaluations of QPM yield performance should be conducted in comparison with genetically similar normal counterparts. This might best be done using newly derived variety counterparts of Hard Endosperm (H.E.) QPM from collaborative efforts of CIMMYT and National Programs where QPM projects are currently underway. This approach would provide answers to the agonizing question that is raised about present performance comparison procedures. It is encouraging to note, however, the near equivalence of yield in recent tests reported by CIMMYT and the example of "Nutricia" QPM tested in Guatemala. "Nutricia" yield was 4.26 t/ha in comparison to 4.34 t/ha for the number one normal variety, ICTA B-1, over 10 locations on producer farms in 1982. More recent QPM conversions LaMaquina 8363 and San Jeronimo 8363 appear to be equally promising.
2. There is urgent need for collaborative efforts between CIMMYT and LDCs for evaluating QPM materials proposed for adoption by specific LDCs. The questions about H.E. QPM yield stability, protein quality and endosperm expression would best be answered by more definitive research through collaborative efforts. Development of specific varieties for certain strategic areas may be appropriate to test for stability and relative performance levels.
3. There is definite interest in collaborative efforts between U.S. universities and CIMMYT in developing temperate region H.E. QPM materials. U.S. universities would offer ideal collaborative assistance to CIMMYT in developing these materials and conducting experiments to validate yield

performance, stability, quality and other factors. These materials are ideally suited for adaptive and basic research, some areas of which are mentioned below.

4. With the ultimate objective of developing materials for either hybrid production or specific variety crosses to take advantage of maximum heterosis, it will be critical that these basic studies are well conceived and executed. There are expressed interests from U.S. scientists in cooperatively evaluating heterotic patterns and gene effects among QPM materials which would have mutual benefits.
5. Collaboration could be effective in the study of inheritance of hard endosperm modifiers in QPM materials. This study could result in simplifying procedures for National programs interested in utilizing the QPM materials for either line-hybrid or variety-hybrid programs where appropriate.
6. Considerable interest exists among U.S. university and CIMMYT scientists in evaluating several gametophyte factors of maize for potential use as a mechanism for genetic isolation of QPM and controlling genetic contamination in production. There are certain limitations in this approach: a) long term effort, b) potential for poor agronomic performances, and c) difficulty in incorporating these factors into elite germplasm.
7. Concern is expressed relative to problems of maintaining genetic purity of QPM materials in commercial production. More definitive evaluation should be made through collaborative efforts among U.S. university, CIMMYT and LDC scientists to establish the most cost effective methods for maintaining genetic purity in production fields.
8. U.S. scientists should encourage collaboration with CIMMYT in evaluating QPM materials for resistance to kernel and ear rot organisms and storage insects. Pericarp splitting associated with much of the QPM material should be researched. These problems are amenable to research which could be effectively done with U.S. universities in conjunction with the development of Northern Temperate Region (NTR), Intermediate Temperate Region (ITR), and Southern Temperate Region (STR) QPM germplasm.
9. Alternative methods should be explored for selecting specific protein quality mutants such as lysine and tryptophan through use of specific amino acid analogues. Collaborative efforts with U.S. universities having expertise in this area would be logical.
10. There is expressed mutual interest in evaluating H.E. QPM for use as a green or vegetable corn. Appropriate questions include: a) effect of stage of development on protein content and quality; b) relationship of carbohydrate properties and

relative preference; and c) general acceptance and utilization of these materials.

11. There is intense interest among U.S. scientists in the study of genetic control of zeins in the CIMMYT QPM materials. The expression of hard endosperm modifying genes in the presence and absence of opaque-2 is appropriate and amenable to cooperative research investigations.
12. For the training of personnel in advanced breeding technologies and in techniques for monitoring QPM materials in target production areas, U.S. universities are uniquely qualified to assist and collaboration should be encouraged.

C. Utilization of QPM

Food acceptance is a complex function dependent on many factors. Even though nutritious foods may be available, people who are unaccustomed to eating them may fail to utilize them in their diet. Food safety, nutritional value and convenience are among the less important reasons for food selection. Any program to improve the diets of people in LDCs must focus on sensory attributes and attitudes which will affect food acceptance. Implementing a QPM utilization program for improving nutritional status of people in LDCs will therefore be a challenging task. Maize will continue to be a high energy food. The utilization of H.E. QPM as a balanced protein source will require special attention to its specific food use, preparation, preference, and keeping quality. It will be important, therefore, to focus on the ultimate usefulness of the H.E. QPM according to the target consumption group.

1. CIMMYT should encourage further collaborative research with U.S. universities specific to the utilization of QPM in the development of traditional foods for target groups. U.S. university scientists have considerable expertise and extensive facilities for food use preparation, including milling and presoaking treatments, evaluating preference, quality after preparation, nutrient digestibility and absorption, protein utilization and keeping quality.
2. Collaborative expertise is also available in U.S. universities for assessing the cost-benefit relationships for alternative protein sources including H.E. QPM. U.S. scientists could contribute significantly to the identification of target populations in LDCs for addressing specific dietary problems.
3. Many countries have a primary interest in QPM as animal feed. China, Dominican Republic, Panama, Haiti and Guatemala are attempting to move QPM into markets at the same price levels as normal maize to encourage its use particularly in swine feed. This could become a major target use for QPM. Collaborative work with U.S. animal nutritionists might provide some critical answers for cost effective nutritional intervention strategies utilizing QPM.

V. CHARACTERIZATION OF BIOLOGICAL AND ENVIRONMENTAL
STRESSES AND DEVELOPMENT OF SELECTION TECHNIQUES

ISSUES

- * Future Directions and Needs in Developing Drought Tolerance.
- * Future Directions and Needs in Developing Disease and Insect Pest Resistance, and in Using New Technologies for Disease and Pest Control.
- * Selection Index vs. Single Criteria for Improving Stress and Pest Tolerances.
- * Breeding for Biomass Production vs. Increased Harvest Index.
- * Utilization of International Testing in Breeding for Biotic and Environmental Stress Resistance.

CIMMYT APPROACHES TO BREEDING FOR STRESS TOLERANCE

Gregory Edmeades*

ABSTRACT

A stress environment is defined as a component of the environment which, because of its state or level of supply, causes a plant or crop to yield less than its genetic potential. In tropical maize some major stresses are radiation, moisture, fertility, temperature, and root zone. These stresses, depending on the degree of strain, may reduce grain yield substantially.

There are two general approaches to breeding for stress tolerance. One uses yield under stress as the sole criterion for selection. The other is the ideotype approach which combines the appropriate traits which will increase yield and yield stability under specific stress situations. The following steps are suggested:

1. Careful assessment of the type of stress likely to occur.
2. Selection of sites where specific stress will occur naturally and reliably, or where such stress can be controlled.
3. Establishment of appropriate ideotype, or ideal plant type, and selection criteria.
4. Examination for genetic variability of selected traits. For recurrent selection programs the establishment of genotype x environment interaction for yield among breeding units.
5. Field selection under stress and normal conditions, normally using yield and other traits as part of a visual or calculated selection index.
6. Recombination and advancement of superior genotypes.

The results obtained at CIMMYT in improving the performance of tropical maize to some of these stresses were discussed.

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PANEL DISCUSSIONS AND RECOMMENDATIONS

Loyal F. Bauman*

Environmental stresses that act as constraints on yield, quality or various performance characteristics involve a large number of interacting factors. The major stresses are diseases, insects, drought, high temperature and nutrient limitations. Modification of expression of these stresses in the plant is generally under rather complex genetic control which interacts with environmental and other stress factors. Breeding for biological control of stresses is therefore generally difficult, involving rather large scale and long term selection programs.

Selection for stress resistance has generally been empirical, with little knowledge of specific genetic systems and the physiological and biochemical mechanisms involved. Nevertheless CIMMYT and other maize improvement projects have been successful in reducing losses from stress factors.

Following is a summary of the various issues presented by the discussion groups.

A. Future directions and needs in developing drought tolerance.

1. Despite some concern there was a consensus that selection under drought conditions is a practical and useful approach. High variability, interactions and low heritability are serious limitations.
2. Research on the biochemical and physiological mechanisms controlling drought tolerance should have high priority. These would be appropriate areas for collaborative research.
3. There is little understanding of the genetic mechanisms involved in drought tolerance. Prolificacy and silk delay interval are plant characters that show some association with drought tolerance.
4. There was general agreement with Edmeade's approach to developing a drought tolerant ideotype, appropriate siting of IPTTs, selection for prolificacy, and divergent selection to document changes associated with drought tolerance. Other suggestions include examination of alternate methods such as high plant density and defoliation for inducing stress.

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5. Other potential areas for collaboration include:
 - (a) development of a stress inventory of maize germplasm,
 - (b) investigation of root function and morphology, and
 - (c) development of appropriate screening methods.
- B. Future directions and needs in developing disease and insect pest resistance and new technologies for disease and pest control.

Discussants expressed the opinion that CIMMYT has done an excellent job in their current programs for developing disease and insect resistance.

1. Current evaluation techniques which are continuing to be improved lead to improvement for pest resistance and tolerance. Development of new techniques would be a productive collaborative research area.
2. More rapid progress could be made if mechanisms of insect/disease resistance were better understood. This again is research primarily suited to collaborative efforts.
3. Models for determining crop losses and economic consequences should be developed, especially for the tropics.
4. Evaluation of host resistance by different screening techniques, particularly those utilizing rate limiting systems would be useful.
5. Research on storage insects and diseases to include estimated losses, mycotoxins, and appropriate storage conditions is urgently needed.
6. Consideration of pesticides not available or not safe to apply in developing countries emphasizes the need for research on biological control methods.
7. Determination on interactions of environment, pests and diseases would be useful in assessing damage and developing control strategies.
8. The effects of polycropping systems on disease and insect infestations need to be investigated and quantified.
9. Physiological and genetic studies are needed on stalk and root senescence, especially in relation to translocation of assimilates from the stalk to prevent invasion by low order parasites.

10. Stress from environmental factors such as weed competition should be investigated.
 11. Research to integrate production and pest control should be conducted so appropriate and practical systems can be developed.
- C. Selection index vs. single criteria for improving stress and pest tolerance.
1. Design of criteria for plant selection, whether a single or a multiple index for stress, pests or combinations, will likely be so specific and complex that determination of the best scheme would be futile or at best, extremely difficult.
 2. Basic research is needed (collaborative effort) to establish which selection index would be most useful for a specific problem. The points to be considered are:
 - (a) magnitude and order in which problems are manifested,
 - (b) genetic control mechanisms and their relationships to physiological and morphological characteristics, and
 - (c) quantitative relationships between plant production and levels of pests or stress.
 3. National programs may provide information on the magnitude of problems and possible selection criteria based on their studies under "real" world conditions.
 4. Concern was expressed whether maize production is being attempted in non-adapted areas making selection of adequate varieties quite difficult. Alternate crop(s) might well be considered.
- D. Breeding for biomass production vs. increased harvest index (HI).
1. Reported results in which biomass remained unchanged and HI increased as shorter plants were selected suggests selection for HI in tropical germplasm may be useful.
 2. Later maturing tropical populations showed greater positive associations of HI with improved yield.
 3. Special attention should be directed towards definition of growth rate observations since individual plant data is not the same as measurements for plant communities on a unit area basis.
 4. Plant ideotypes should be developed for tropical maize as those developed by Mock et al. for temperate maize.

5. Research is needed to study associations of physiological traits and performance. This might best be done as a collaborative effort.
 6. CIMMYT populations are highly variable and should be appropriate genetic material for relating physiological traits to performance.
- E. Utilization of international testing in breeding for biotic and environmental stress resistance.
1. There is a need to evaluate germplasm for resistances prior to the breeding process.
 2. CIMMYT uses a number of test locations to evaluate stress resistance in their worldwide adaptation program. Some national programs may have different priorities so populations would need to be adapted to more specific environments.
 3. CIMMYT and university scientists should initiate bilateral programs to more thoroughly investigate applicable stress resistant mechanisms.
 4. Biotic and pest resistance of breeding populations need to be identified, documented and environmentally evaluated. This information would be of great value to national programs for selecting best germplasm sources.
 5. Waxy leaf types present in some tripsacums should be investigated for their use in reducing transpiration and subsequent contribution to drought resistance.
 6. CIMMYT and National Program scientists should cooperate more in evaluating their respective germplasm and needs.
 7. Reduced tillage practices are becoming established which may contribute to an increase in environmental and pest stresses.

There are a great number of stress areas that would be high priority for collaborative research and training efforts between CIMMYT and university scientists. These efforts should be between scientists with mutual and compatible research interests, and having adequate expertise and facilities.

VI. ON-FARM RESEARCH PROGRAMS FOR MAIZE

ISSUES

- * Adequacy of On-Farm Research Methodology to Provide Useful Results in LDC Breeding Programs.
- * Role of OFR in Developing/Extending Agronomic Production Programs With Improved Varieties.
- * Identification of Problems and Needs Through OFR and Feedback to CIMMYT and National Programs.
- * Production Research Necessary to Backstop On-Farm Research Programs.
- * Role and Requirements of LDC National Programs for Effective On-Farm Research and Maize Production.

ON-FARM RESEARCH AT CIMMYT

Alejandro D. Violic*

In its Mexico training programs for agronomists specializing in improvement, production, economics and technology transfer, CIMMYT has developed a model strategy organized in five stages that includes research in experimental stations and research verification of technological alternatives in farmers' fields, under actual conditions of production. This model has served in training more than 600 specialists from Latin America, Asia and Africa, and has also been adopted by some developing countries.

The first stage in this model, Research in Experimental Stations, consists of research requiring highly controlled conditions in order to realize genetic improvement (breeding), evaluate new chemicals involving risk, etc. The work in the other four stages is conducted in a number of farmers' fields representative of the production technologies and socio-economic conditions of the region, and involves the joint efforts of biological scientists, agricultural economists, extension workers and farmers.

In the second stage, Exploratory Research, an agro-economic survey of farmers and multifactorial two-level agronomic experiments are conducted in order to identify a minimum number of critical limiting factors responsible for the low production in the area. The joint participation of research scientists, extension workers and economists in this work is an attractive alternative for the solution of the age-old problem arising from the independent actions of specialists.

The factors identified as limitations to production are investigated in more detail in the third stage when Multilocation Levels Experiments are conducted for the quantitative description of the crop response to each important management factor. The results are submitted for agronomic, statistical and economic analyses. This permits the technical team to formulate technological management alternatives with different levels of return and associated risks.

These management alternatives are subjected to a Verification Process, the fourth stage, in larger plots, at many locations, and involving the largest possible number of farmers. This fourth stage is the responsibility of the extension workers. As a modification of this stage, superimposed verifications have also been used. The results of verification trials and the farmers' reactions to the new technologies provide the feedback necessary for guidance and rectification of plans for future research work in stages one, two and three.

In stage five, the technologies accepted by farmers are verified in Experimental Production Plots, one hectare or larger, for more precise economic analysis and demonstration purposes.

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CONSERVATION TILLAGE -- A TECHNOLOGY THAT
EMERGED FROM ON-FARM RESEARCH

Arnold F.E. Palmer*

Conservation tillage has emerged from CIMMYT on-farm research in Mexico as a very promising technology for lowland tropical maize production. Research on conservation tillage was carried out in the maize production research stage of the CIMMYT training program over 18 crop cycles. It has demonstrated advantages in terms of cost savings, soil and water conservation, yield stability and risk reduction.

The research area in the northern part of Veracruz state at 21° N. latitude, has rolling topography at altitudes below 200 m. Mean annual rainfall is 1200 mm with considerable year-to-year and seasonal variation. The soils are heavy vertisols so that timing of cultivation for seedbed preparation and weed control is difficult. Drought and waterlogging are frequent problems. Hand hoeing is the most common method of weed control. Due to the climate and shortage of labor, hoeing is frequently untimely and ineffective.

Conservation tillage utilizing atrazine in combination with paraquat, glyphosate, 2,4-D or dicamba, has produced the same yields as conventional tillage in normal seasons and higher yields in drought seasons.

Appropriate equipment for conservation tillage under the conditions faced by small farmers in developing tropical countries was discussed with emphasis on small-scale, inexpensive equipment for the critical operations of planting and herbicide application.

While conservation tillage shows great promise in the study area, location-specific research needs to be conducted to determine its value in other tropical areas where maize is grown as an inter-crop in complex rotations, during an extended dry season, for animal fodder competing with the use of stover for mulch, or where there are termites. Research is also needed on conservation tillage where there is a different spectrum of weeds.

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ON-FARM RESEARCH METHODS IN THE ANDEAN REGION
OUTREACH PROGRAM

James B. Barnett*

In many developing countries the effectiveness of research is diminished due to lack of orientation of research to the client farmer's needs, poorly defined methodology leading from applied research to farmer acceptable recommendations, insufficient understanding of statistical designs, field plot techniques and interpretation of data, and poor communication links between research and extension.

To resolve these problems an on-farm research program was developed with well defined phases. This program is conducted jointly by research and extension workers. An informal exploratory survey is conducted to define the recommendation domains and the research opportunities within these domains. Those research opportunities appropriate for on-farm research are placed in either the exploratory or the determinative phase. The exploratory phase, in which a two-level factorial arrangement is used, compares the farmer's practice with a proposed practice. Proposed practices which have no comparative advantage over the farmer's practice are eliminated from further research while those which do have an advantage are placed in the determinative phase. In the determinative phase input options are compared and subjected to both statistical and economic analyses. The most promising of those options are then placed into the verification phase. This is the final research phase. Those options which demonstrate stability and have a high probability of immediate acceptance by the farmer are used in demonstration plots. A follow-up survey is conducted to quantify farmer acceptance and this information is fed back into the research system.

This on-farm research procedure was promoted by a system of in-country training seminars. Research and extension workers are required to attend a series of three seminars conducted in a target area during the cropping cycle. The first seminar, at planting time, includes the survey technique, experimental design, field-plot techniques and field experience in the subjects. Using the survey data, trials are designed and planted in farmer's fields. The second seminar, at mid-cycle, includes agronomic and economic data gathering techniques and other subjects of maize agronomy. In the third session the trials are harvested and the data subjected to statistical and economic analyses. Using these data the next cycle is planned and a report of findings is written. Follow-up training is accomplished through post-harvest seminars. The CIMMYT regional agronomist also visits researchers and discusses their individual programs.

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PANEL DISCUSSIONS AND RECOMMENDATIONS

Margaret E. Smith*

Introduction

The subject of on-farm research programs for maize is certainly among the most important topics discussed during this conference. It is, after all, the on-farm phase of a research program which establishes contact with the program's clients, the farmers; allows for the tailoring of alternatives to the specific production constraints faced by those clients; initiates the process of technology transfer to farmers; and permits the farmer-to-researcher feedback which is essential to ensure that research goals are adjusted to address actual production problems. The research process should begin and end with the farmer, and on-farm research provides the necessary link.

Despite the obvious importance of this phase of research, it was perhaps the most difficult area to present and discuss for several reasons. First, national on-farm research is actually the responsibility of national programs, not directly CIMMYT's responsibility. Certainly CIMMYT makes a very important contribution to many national on-farm research programs through their Maize Training Program and through the support of regional outreach programs and bilateral programs with specific countries. Staff from the Economics Program are usually involved in these activities. Nonetheless, national on-farm research must be carried out primarily by national program personnel with their own resources and assistance provided by CIMMYT regional staff.

A second difficulty in discussing this topic was that, unlike the situation for genetic engineering, breeding for stress tolerance, and some of the other topics discussed, on-farm research is an area in which expertise is perhaps more concentrated within the network of international centers and national programs than within U.S. universities. This is not to say that specific individuals or departments with strong expertise in on-farm research programs do not exist in some universities; quite the contrary. On the average, however, the concentration of expertise is not as great as for more traditional and basic research disciplines. Consequently, it was difficult to identify areas where these universities might have a comparative advantage. Furthermore, lack of familiarity with the methodological and practical limitations encountered in on-farm research makes it difficult for some university researchers to visualize areas of potential collaboration.

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Despite these complications with the topic of on-farm research programs for maize, discussions yielded several interesting ideas concerning CIMMYT's program, and concerning collaboration between national programs, CIMMYT, and U.S. universities. These fell into the following four broad categories, which are discussed individually in the remainder of this report: (1) comments concerning CIMMYT's program; (2) graduate training needs; (3) specific basic research needs; and (4) possibilities in university bilateral programs with specific countries.

Comments Concerning CIMMYT's Program

Although the main objective of this report is to summarize areas of potential collaboration involving U.S. universities, a few comments which came out regarding CIMMYT's efforts in on-farm research programs are included here. In most cases these comments lead to perceived areas for collaboration and thus serve as background for the next three sections.

One of CIMMYT's primary contributions to on-farm research is through training, and this training is carried on in many ways. The conference emphasized the Maize Training Program's activities in Mexico. Beyond these, there are in-country training programs, regional workshops (i.e., the one with the University of Zimbabwe), and the training that occurs as CIMMYT staff work with national program staff involved in on-farm research. CIMMYT also supports on-farm research through the development of procedures which further its application.

CIMMYT staff was complimented for their efforts in minimum tillage applications to small farms. They were also complimented for maintaining simplicity in their on-farm research methodology, and several successes in feedback from on-farm research to the breeding program were recognized. The following needs were identified:

- 1) More in-service training programs for national personnel.
- 2) Analysis and publication of data from on-farm research programs to allow evaluation of the methodology used.
- 3) Linkages between U.S. universities and CIMMYT which will permit the universities to respond to basic research needs identified through on-farm research programs with which CIMMYT is associated.

The major point to emerge from this discussion, both a compliment to CIMMYT's current efforts and a caution to all those involved in on-farm research in the future, was that it is essential to maintain a continued emphasis on strong, well developed experiment station research as the basis for good, strong on-farm research.

Graduate Training Needs

With on-farm research programs, as with most of the topics discussed in this conference, graduate training was seen as an area in which universities have a comparative advantage and could well

collaborate with CIMMYT. As mentioned previously, however, on-farm research per se is not an area of strong expertise in most U.S. universities. Thus, special efforts would be required to make training relevant and useful to graduates planning to work in on-farm research programs. The following suggestions were made regarding graduate training:

- 1) Broad training, including both research oriented work and extension training, is essential for professionals who will be working in on-farm research programs.
- 2) Every effort should be made to allow students from developing countries to conduct thesis research within their own national programs or with international center programs in similar areas. Interaction between students doing thesis research and the CIMMYT staff working in a region should be promoted.
- 3) Graduate training should emphasize statistical methods useful in the analysis of on-farm research data, and a special effort should be made to emphasize importance of the interpretation of statistical results.
- 4) Awareness of farming systems projects with the U.S., such as the Farming Systems Support Project (FSSP), should be increased and students should be encouraged to participate in short courses, workshops, and other activities organized by these groups.
- 5) It would be useful to establish a mechanism for maintaining contact between alumni working in national programs, U.S. university personnel with whom they worked, and CIMMYT regional staff.

The overall conclusion concerning graduate training for students from developing country national programs was that a strong effort should be made to stress the importance of understanding farmers' conditions and needs, and gearing research at all levels towards responding to these needs. It should be made clear that simply following the U.S. model for research and extension is not necessarily appropriate or productive.

Specific Basic Research Needs

The goal of on-farm research programs is to develop technology appropriate to the circumstances and needs of farmers in specific areas. This implies that an integrated approach, involving on-going efforts by researchers working in the local area is required, but it is not immediately obvious where university researchers in the U.S. can contribute to this process. There are, however, areas of basic research which can provide needed information or tools to those individuals working in on-farm research. The following areas were identified:

- 1) Technical research questions requiring rather detailed basic studies could be carried out by universities, perhaps as student thesis research in some cases. These might include, for example, the study of varietal interactions with cropping systems or testing

sites (experiment station vs. farmers' fields) to establish the extent to which test results can be extrapolated, the identification of and development of control methods for insect and disease pests, and the study of herbicide action in tropical soils and the effects of management practices on this action.

- 2) Direct support and consultation from university personnel and programs may be appropriate. This might include support from the Soil Management CRSP and the Soil Management Support System of the USDA Soil Conservation Service for classifying and characterizing soils in on-farm research program target areas, and consultation for the identification and possible approaches to specific production constraints. University inputs might also be of benefit in the identification of socio-economic factors which are limiting transfer and adoption of technology.
- 3) Research is needed in some cases to develop appropriate methodologies to be used in on-farm work. The development of methods and models for the on-farm assessment of disease, insect, and weed damage is one such case. Also needs were expressed for refining and clarifying the process of developing recommendations and for improving the efficiency of analysis of data from on-farm research, and feedback of these results to breeding and agronomy research programs.
- 4) Finally, a potential contribution of basic research by universities to on-farm research in national programs was identified in the area of policy. Considerable expertise exists in this area within some universities, and could well be taken advantage of. The caution was expressed that on-farm researchers not fall into the trap of blaming policy issues for the non-adoption of appropriate technologies. However, there are certainly cases where agricultural policy limits the alternatives available to farmers, and insight into methods for changing such policies would be extremely useful.

Farm modeling can be developed to analyze the potential effect of both new technologies and alternative policies to facilitate their introduction. Programming models can help identify constraints and provide more information to researchers about constraints to new technology introduction. This should facilitate collaboration between biologists and social scientists. It also appears to be the most relevant tool to consider the potential impact of alternative new policies in combination with new technologies.

Possibilities in University Bilateral Programs

Both CIMMYT and some U.S. universities have bilateral programs which provide direct support to the countries involved. Hopefully the universities and CIMMYT can complement each other through these programs, each providing support for different national programs. Some

of the specific areas where bilateral programs might contribute to national on-farm research programs are as follows:

- 1) Development of the infrastructure necessary for effective on-farm research within national programs.
- 2) Tailoring of on-farm research methodologies to specific national circumstances and needs.
- 3) Building strong research-to-extension linkages.
- 4) Promoting establishment of regional networks to facilitate exchange of national program, CIMMYT, and university experiences in on-farm research.

In order to improve the quality of research done as a part of bilateral programs, and of support or consulting services provided by researchers from U.S. universities, it was noted that better preparation of U.S. technical teams, especially in the area of on-farm research, would be extremely helpful. Perhaps the universities can look to CIMMYT for help in this area, and request that CIMMYT consider providing orientation to U.S. technical teams going overseas.

TRAINING OPPORTUNITIES AND POSSIBILITIES

Training: The CIMMYT Perspective

**Advanced Degree Training Opportunities And
Challenges**

TRAINING: THE CIMMYT PERSPECTIVE

R.L. Paliwal*

Training For International Service

Many universities in the United States offer courses in the field of international agriculture. Young U.S. scientists often wish to work in some field of international agriculture. They could be better prepared for this assignment if they had an opportunity to do their thesis research at an international center like CIMMYT, where they would be more exposed to the problems of international agriculture and could interact more closely with international scientists.

Frequently U.S. students studying at U.S. universities have expressed a desire to do their thesis work at CIMMYT. They are not able to do so, however, because of lack of funds. It would be useful if the funding for such joint study programs could be available from USAID/BIFAD through a CIMMYT/U.S. universities collaborative program. The number of such students could not be large because of limitation of facilities at the Center.

Short Course Programs

Some U.S. universities provide organized short-term courses on specific subjects which are of relevance to agriculture in the developing countries. International centers like CIMMYT could be helpful in selecting suitable candidates from developing countries to attend these courses.

CIMMYT, on the other hand, organizes in-country training programs in some developing countries and the assistance of U.S. scientists could be very helpful in providing specific expertise for these. Participation of U.S. scientists in training programs at CIMMYT for specific subjects or lectures would also be very useful.

Trainees and visiting scientists who come to CIMMYT for training programs could further broaden their experiences through visits to U.S. universities. So far such visits have been arranged in a rather random manner. The subjects of interest to these trainees and visiting scientists include hybrid maize development, seed production and technology, physiological aspects of breeding, insect resistance, virus diseases, conservation tillage, food technology, industrial uses of maize, etc. These visits could be more meaningful if an intensive 3 to 4 day program could be organized for a small group having common interests, and the university is selected for competence in the subject and an infrastructure to handle such programs. Short duration, intensive programs would be very useful for improving technical personnel in the developing countries.

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Collaborative University - CIMMYT Programs

Another area for collaboration between CIMMYT and U.S. universities is the graduate training of students from the developing countries which is sponsored by CIMMYT. Some universities like Minnesota, Cornell, Kansas State, and Nebraska have been collaborating closely with CIMMYT and a larger number of students which we sponsor go to these universities. This cooperation needs to be extended so students from developing countries will have exposure to a wide selection of universities.

ADVANCED DEGREE TRAINING OPPORTUNITIES AND CHALLENGES

James C. Sentz*

I want to take this occasion to discuss certain aspects of post-graduate training in preparation for research and teaching in developing countries. Remember first that it is people who do research: university professors, research scientists, and post-graduate scholars. Research training is an interactive process at the personal level, and requires a professional and academic environment which conditions the orientation of training from "ivory tower" to "demonstration."

Graduate education and training is a major component of our U.S. Land-Grant University system. Advanced degree training is what we do, and we believe we do it well. I expect all of us here would agree that our U.S. universities have a comparative advantage in this function. But do we have a singularly comparative advantage for the 'best' training of research and developmental scientists and educators for developing countries? Let me suggest that we do not, and that we could greatly improve our programs for this purpose through cooperative efforts with the IARCs and developing country institutions.

Our U.S. Agricultural University Graduate Training model has evolved to serve our domestic needs in the 1980s. But we can readily adopt this system to simultaneously better serve developing country agricultural programs. Where fundamental biological knowledge is the issue, this model is clearly effective since there are no environmental constraints. Adaptive and applied research, however, are sociologically and economically bound. Both of these are critical variables and are a part of the applied research problem. Neither the transfer of our science to developing countries, nor its advance within these countries, can be effectively accomplished then within our university campuses in the absence of the appropriate environmental setting. But we do have considerable opportunity to expand our training environment for maize research and production through cooperation with CIMMYT and its global maize program.

The potential for impact from such a cooperative effort alone would be a major thrust towards increasing maize production worldwide. This impact would be realized by: (1) directing increased research into critical problems through dissertations and theses; (2) training with appropriate materials and within appropriate environments, such as International Centers and home countries; and (3) establishing increasing numbers of developing country nationals in productive programs as a direct spinoff from doing degree research in their home institutions. It is this combination of teaching scientific research principles through their application to real-world problems which was so successful in the evolution of our U.S. system of training. We need now only extend our network of laboratories and research stations to effectively extend our training model to better serve developing country programs.

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Two critical components of our degree training process must, however, remain under control of the degree granting university: (1) assurance of integrity of the research; and (2) the professor - scholar interaction on a regular basis, particularly during the dissertation period. Various mechanisms can be utilized to provide for these through cooperative arrangements with IARC professional staff at headquarters and in the field, with selected professionals in developing country programs, through travel support for academic advisors, and research support in-country for the scholar.

Dissertation research in developing countries has been accepted widely in agricultural economics. This procedure has been used less in the agricultural and biological sciences, but it has been successfully employed by a number of universities: Cornell, with a variety of programs is perhaps best known, Minnesota, with a current program in Morocco, Michigan State and others.

Some quick calculations will demonstrate that the monetary cost of dissertation research either in-country or at CIMMYT is no more, and perhaps less, than for completing the research within the U.S. Some additional time may be required to complete the degree when it is done in-country. However, more relevant research, establishment of home country programs, and the increased participation of U.S. scientists as academic advisors in developing country agricultural problems will more than justify the disadvantages and additional efforts necessary.

My comments to this point have focused on training individuals. We also need to focus more sharply upon developing national programs, "the frontlines" for production, to further impact world maize production. For success at this program level we need also to focus upon the training and integration of individuals from various disciplines, and staffing programs at a "critical mass" level to be effective. This task in maize will require "the best cooperation" between the CIMMYT global program and our university scientists. A collaborative program effort of this kind could be implemented with few additional resources, and have great potential for impact. It would require careful planning and cooperation, but the results would be greater than the sum effects of our individual U.S. and CIMMYT efforts. I truly believe this is one of the greater opportunities within our grasp today.

All of the discussion reports during this conference have mentioned the role and value of training within their specific context, either as a component of recommended programs, or as a mechanism to accomplish some proposed activities. Post-graduate training, as a mechanism for doing important and relevant research, is a common denominator for collaborative programs as well as a direct objective for cooperative effort in assisting the establishment of developing country national maize programs.

SPECIAL REPORTS

Cooperative Research on Aflatoxin

**Basic Constraints to Maize Productivity
in Tropical Africa**

**Can the Success Story of Hybrid Maize in Kenya
Repeat Itself in Nigeria**

COOPERATIVE RESEARCH ON AFLATOXIN

Marcus S. Zuber and Larry L. Darrah*

One very serious problem that has not been specifically addressed at this conference is aflatoxin contamination of maize grain. The toxin is produced by the fungi Aspergillus flavus and A. parasiticus growing on maize kernels.

Aflatoxin contaminates maize grain most frequently in the tropics and subtropics, but occasionally is found on maize grain grown in the temperate zone. Infection takes place on the kernel in preharvest maize. Infection and subsequent aflatoxin production is enhanced by ear damaging insects and periods of stress (heat and low soil moisture) during grain filling.

In areas where maize grain is consumed directly by humans, it can become a very serious health problem since the toxin is a very potent carcinogenic agent. Evidence has been accumulated showing that human and animal deaths have been caused by consuming aflatoxin contaminated maize. The toxin is resistant to high temperatures and can only be decontaminated by ammonia treatment, which makes the grain unfit for human consumption. However, it is then satisfactory for chicken, swine, and cattle feed.

Genetic resistance in maize to Aspergillus species for reducing levels of aflatoxin contamination or eliminating the problem entirely has been researched for the past ten years. Very little success has been achieved. Significant differences for aflatoxin levels among genotypes have been reported for a single year, but results have been very difficult to repeat, suggesting a large environment by genotype interaction.

One of the greatest handicaps in these studies has been the lack of suitable inoculation methods. Some researchers have now turned to planting material in areas where the likelihood of natural infection is great. Research on genetic control of aflatoxin is long term and should be continued vigorously.

Other means of reducing aflatoxin contamination in maize center around management practices that reduce insects and stress during the grain filling period. It has been shown that irrigation and early planting dates which reduce stress will reduce aflatoxin contamination. A. flavus is a very weak invader and usually needs help to establish an infection site on the ear. Therefore, the many ear damaging insects serve as predisposing agents or vectors. The development of maize genotypes with high resistance to these insects is a very promising approach for indirectly controlling the problem.

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Several U.S. universities are conducting research on the aflatoxin problem which was most serious in the southeast United States in 1977 and 1980. This problem would be an excellent candidate for cooperative research between U.S. universities, CIMMYT and LDCs.

BASIC CONSTRAINTS TO MAIZE PRODUCTIVITY IN TROPICAL AFRICA

Joseph M. Fajemisin*

Maize is primarily a staple food crop in tropical Africa. Over 80% of the countries in the region have per capita maize consumption values greater than the world average. The average annual increase in production of 1.9% over the past two decades, attributed almost entirely to increased hectareage, when compared with the current population growth rate of 3.0% will produce a net deficit of over 40% by the year 2000. Yield has stagnated at about 1 ton per hectare. It is the least productive region in the world with less than 30% of the world average.

Maize is produced in five major ecologies in tropical Africa which are determined primarily by rainfall regime and magnitude of the prevailing altitude. They are lowland rainforest, lowland moist savanna, lowland dry savanna, mid-altitude and highland. The low productivity of maize in Africa results from an interaction of the following major factors:

1. Climatic parameters, such as rainfall volume and distribution, solar radiation, and their effects on basic crop growth
2. Biotic factors comprising important diseases and insect pests, many of which are specific to the region
3. Soil fertility factors
4. Frequency of drought
5. Inefficiency of prevailing crop management practices
6. Poor infrastructure as related to manpower, technology development and transfer and production incentives

These constraints are explained in some detail with a view to developing appropriate techniques for reducing their effects through problem-solving oriented crop improvement, and the investigation of agronomic studies designed to ascertain the optimally feasible microenvironment that will guarantee the expression of high yield potential.

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CAN THE SUCCESS STORY OF HYBRID MAIZE IN KENYA
REPEAT ITSELF IN NIGERIA?

Yoel Efron¹ and Soon K. Kim²

The concept of the Green Revolution has emerged through the work of CIMMYT and IRRI in wheat and rice. Factors such as varieties, fertilizers, extension, credit, pricing policy and marketing contributed to the dramatic increase in production of these two crops in the LDCs. However, the availability of high yielding management responsive varieties was a major factor triggering the interest of farmers and policy makers in using and developing the other necessary components for success.

In maize, despite progress in varietal improvement, only sporadic success stories of increased production and self-sufficiency exist. One success is production of hybrid maize in Kenya. In a period of 10 years the use of hybrid maize varieties in Kenya increased from an initial 160 hectares to at least 320,000 hectares. Hybrid maize grown by small holders accounted for roughly half the country's total production. The hybrids produced a remarkable 40 percent increase in yield. The availability of high yielding hybrids promoted the establishment of an aggressive seed company that produced, distributed and promoted hybrid varieties throughout the country with extension agents demonstrating their use. The Government supported an official price and marketing system.

The Kenyan hybrid success story was considered unique in Africa. Attempts are presently underway in Nigeria to create a similar success story. Nigeria has governmental awareness, price incentives, a market for the maize and satisfactory infrastructure -- conditions that will promote commercially oriented agriculture.

A hybrid maize project was initiated at IITA in 1979 with major emphasis on development of tropically adapted, disease and insect resistant lines with good combining ability in national programs. The lines were developed from the best available germplasm from CIMMYT, IITA, national programs and the United States. In 1982 the work on hybrid maize was intensified upon request and with the support of the Federal Government of Nigeria. During this year, about 1,000 S-5 lines were tested for combining ability, performance and adaptability in several Nigerian locations. Based on these trials, 73 inbred lines were selected and used to produce about 400 experimental single cross and top-cross hybrids during the dry season of 1982. These hybrids were tested during 1983 in several Nigerian forest and savanna locations using four-row plots with four replications.

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Despite drought conditions, especially in the savanna area during the 1983 cropping season, results of these trials were encouraging. Hybrid 8322-13 yielded an average of 9.1 t/ha across four savanna locations with a range of 8.8 to 10.6 t/ha. This hybrid was high yielding (7.6 t/ha) at Ikenne, a representative site of the forest zone, which indicates its stability across locations. A record yield of 12.1 t/ha was obtained in Samaru with the hybrid 8324-18.

The excellent performance of the hybrid trials was especially noticeable because of a severe epidemic of maize streak virus throughout the savanna. Most of the hybrids were resistant. The testing site at Mokwa, in the Guinea savanna zone, was severely affected by drought and striga (witchweed). A number of hybrids, including 8322-13, were identified as having a good level of resistance to this parasitic weed.

Based on the 1983 trials, 24 hybrids having significantly higher yields than the control open-pollinated varieties were selected for further testing in Nigeria in cooperation with the national program (NCRI and NAFPP). On-farm demonstration trials were composed of 0.1 ha units for each hybrid with an open-pollinated check variety. Seed production was carried out for these trials during the dry season of 1983 and a three week training course in hybrid seed production was organized at the same time. More than 150 on-farm demonstration trials consisting of 3 to 8 0.1 ha units were planted across Nigeria. The trials planted in the forest area are presently being harvested.

The excellent performance of the hybrids in 1983 and the demonstration trials in 1984 has already produced a stimulating effect. The hybrid project is considered one of the most significant contributions of IITA to the economy of Nigeria. A private seed company was established in 1984, a result of the hybrid project. That company, with the technical assistance of IITA and the National Seed Service, is engaged in experimental hybrid seed production with contract farmers on an area of about 200 ha.

Commercial production of hybrid maize on a large scale may become a reality in Nigeria in the near future. Miracle varieties alone cannot bring about increased production. A success in increased maize production in Nigeria will become a reality only with hard work, improved management and full support of the Government.

ORGANIZATION AND STRUCTURE FOR COLLABORATION:

POSSIBILITIES AND POTENTIAL

PANEL PRESENTATIONS

- John Stovall Introduction
- Robert D. Havener Collaboration from CIMMYT's
Perspective
- D. Woods Thomas Collaborative Mechanisms
From the University Perspective
- Robert W. Kleis Essential Elements of an
International Network for
Collaboration in Maize Research
- Dale D. Harpstead Where Do We Go From Here?
A Proposal for Continuing
Collaboration

DISCUSSION

John Stovall - Moderator

RESOLUTION

CHARGE to AD HOC WORKING GROUP

INTRODUCTION

John Stovall*

Greetings from the Board for International Food and Agricultural Development (BIFAD). I want to express regrets from Dr. E.T. York, Board Chairman, who is not able to attend this workshop because he is out of the country, and from Dr. Fred Hutchinson, Executive Director, who also wanted to attend but could not for a variety of reasons. As most of you know, BIFAD has had an interest in this kind of activity for some time. We are very much interested in what you are trying to do and will be anxious to know the results of this workshop. One statutory responsibility of BIFAD is to more fully involve U.S. universities in the International Agricultural Research Center (IARC) network and this conference promises to be a very important accomplishment in that regard.

Why did we organize this session? It is one thing to identify work that needs to be done, but it may be quite another thing to identify the hurdles and the mechanisms that have to be developed for the work to be accomplished. It is for this purpose that we have assembled this panel; to determine, if possible, what needs to be done to get this important work going. We hope they can identify a) some mechanisms that have to be put into place, b) some administrative arrangements that need to be made, and c) the best organizational structure to accomplish what we would like to do.

The panelists I note are all 'seasoned' administrators who have probably been down a few dead ends in these kinds of things, and perhaps they can help us avoid similar dead ends. I should tell you they have done a fair amount of homework. They have met three times during the course of this workshop and have had the benefit of input from a number of people. To some extent, then, what you will hear in this session is a report of those discussions and their conclusions. Following their remarks we will entertain discussion from the floor, and then seek your action on a proposal summarizing and concluding this conference.

*Chief for Research, BIFAD, U.S.AID, Washington, D.C.

COLLABORATION FROM CIMMYT'S PERSPECTIVE

Robert D. Havener*

When you think about collaborative research as viewed by CIMMYT, you must remember we are very much an applied mission oriented research institute. We are constantly choosing among many priorities and targets of opportunity. At any one time we can address only about 10% of the things that would be interesting to do, so we have to be fairly careful to choose targets of high priority and opportunity to work on at any particular time. When there are new breakthroughs which appear useful, say in DNA transfer or in molecular biology, we will move quickly to bring them into our adaptive and applied research programs, provided we are aware of and know how to manage them. We are not disinterested in these subjects, but given scarce resources, our interest is always at the applied end of the research spectrum. We usually pursue those things which have a relatively short-term payoff.

I would like to describe some typologies that already exist for collaboration between research institutes and with universities, and talk about their components and usefulness. The collaborative research operations in which we engage generally can be collapsed into four types.

1. CIMMYT Provides Seed or Other Biological Materials having known genetic background, sources, or agri-climatic conditions in which it was evolved, to researchers who have a fundamental research capacity and interest. The mycotoxin work at the University of Missouri is a good example of this. Essentially no money changes hands; they support their part of the work and we have resources to do our part. We have gotten together on what we consider to be an important issue. We try to provide them with what they need to best do their work, and they try to provide us with research results that will help guide research programs in the future. There is no administrative bureaucracy; an exchange of letters constitutes the contract. This is the best kind of collaboration in which we find mutuality of interest, common goals, common purposes and have separate resources directed toward a common objective. It is mutually supporting and the kind of collaborative association we like best.
2. CIMMYT Endorsement. Frequently an organization comes to us asking our endorsement of a particular research project. If we think it is a good project we will help them develop the proposal as it applies to the tropics and subtropics in the developing world and support the findings of their proposal with USAID, the Ford, Rockefeller or Kellogg foundations, or other potential sources of funding. In these cases we are not principally involved in the execution of the contract, only essentially legitimizing it.

*Director General, CIMMYT, Mexico

3. Direct Contract Research is an area we have mentioned very little, but which we can and occasionally do using our own core monies to obtain expertise and/or facilities in a particular area. We have such contracts with the National Institute of Nutrition here in Mexico, INCAP in Guatemala, the Nutrition Institute in Peru, and with the University here at Chapingo for the use of their soils laboratory. When you have areas where you believe the utilization of your capacity for CIMMYT's purposes would be cost effective, we wish you would call them to our attention. If it is cheaper for you to do it, we would be delighted to pay you to do it, unless it is a training function or some other spinoff that we do not normally contemplate.

4. True Collaborative Research. This is the case where we both agree we should mutually do certain things in different locations, and that doing more of it would be very important if the resources were available. Under these circumstances we prepare a joint proposal for consideration of an appropriate donor and mobilize support for it. I think this is the type of research we will be focusing most of our attention upon during the balance of these discussions. But I wanted you to know that simple collaboration with no exchange of money and no bureaucracy is possible when based upon mutual interests. We can endorse important projects of mutual interest if they come to us early. Occasionally it can be helpful to get CIMMYT endorsement if the donor money is international. Sometimes we can perform a useful role through the endorsement process, confirming that contract research is possible and that we are seeking more collaborative research in a common mode with U.S. universities, with national programs, and with institutes in developing countries.

We did not talk as much as we might have about ways in which we can have tripartite collaboration between research institutes in a developing country, the United States, and one such as CIMMYT. I think there are several opportunities for this emerging as research institutes in developing countries grow stronger, get more modern equipment, and frequently have low cost labor and under-utilized facilities. This offers some possibilities that ought to be further explored.

There are three mechanisms I would like to mention briefly because CIMMYT's problem is perhaps unique in this area.

1. Graduate Student Research

We have limited capacity for graduate students working on advanced degrees. Such programs must be on a problem of mutual interest and have a reasonably quick payoff with a visible impact potential for developing countries. We can handle only a few such students in any given year; but this can be a relatively inexpensive way for you to get research done in the tropics that may be of relevance to your objectives, for the student to get experience working and living in the tropics, and for us to get important studies done essentially on a contract basis. Normally we would expect you to provide support for your student in the normal pursuit of their

degree. Frequently we can provide land, labor, seed, and local operating costs; and occasionally we may be able to provide part of the local sustenance.

2. Sabbatical Studies

We have not done this kind of exchange recently, but both Dr. Cantrell and I would like to explore more fully the possibility for people like yourselves to come here for sabbatical study with very well defined purposes and programs of mutual interest. If our limited facilities can fulfill your needs, and the purposes of your research can fulfill our needs, then we would like to make a bargain with you on a shared cost basis.

I remind you that we are a very small research organization. We have about 25 senior and international scientists working on the problems of maize in all our locations. This means that when we talk about entomologists we're talking about John Mihm; when we talk about pathologists we're talking about Carlos De Leon; and when we talk about agronomists and physiologists we're probably talking about Greg Edmeades. So our capacity to do true collaborative research is quite limited. We are about one deep in most major disciplines other than plant breeding, and we think our plant breeders are occupied about 366 days out of the year. So again, we must choose our targets carefully.

3. Collaborative Research

This is something we definitely do want to expand. We would like to tap your resources, your energy, and your intelligence as often as we can. You may not believe this, but we prefer that any money which is mobilized go to you, rather than to us. There are occasions when, for your convenience, we could accept the funds at CIMMYT. For example, because of our small and flexible organization, we might get by with lesser overhead costs than your universities. Generally, however, we would prefer to mobilize such money and that it go to your institution and to you as the professional because there is the tendency for people to look at our global budget and think CIMMYT is getting big and fat and has too much money. So we would really prefer that collaborative funding flow to you whenever possible.

COLLABORATIVE MECHANISMS
FROM THE UNIVERSITY PERSPECTIVE

D. Woods Thomas*

It's a real pleasure to be back at CIMMYT. A number of years ago, when the Purdue and CIMMYT folks were working closely together on opaque-2, I visited here and learned a great deal about corn breeding. But during this week, I have discovered it was insidious knowledge. I am very impressed with the session here this morning. It has been completely open, very objective, and a great many ideas have emerged. We have identified an impressive list of potentially important collaborative research activities. This is something I have been immensely interested in promoting for some time in a variety of ways, and I am delighted this conference is taking place. The substance of what you have done here this week is extremely important.

There are two kinds of things that we need to think about. One, the reason Bob Jackson is in the center of this table, is the source of money. The other is the kind of inter-institutional mechanism needed to make some of the good things happen, assuming we can get enough resources. I believe that particular institutional mechanism, whatever it is, will have to be site specific for maize and for the kinds of problems we have been talking about. It will have to be tailored to the collaborative research activities which have been identified here. In this context there are three kinds of mechanisms which we might learn from and draw upon in putting together a site specific mechanism that will serve these purposes.

1. Scientist to Scientist

The first mechanism that comes to mind is a scientist-to-scientist, informal, and non-bureaucratic structure. The more of this we can do the better, because that is where the real work is done. There is quite a lot of informal collaboration going on and no one wants to see it stopped, but there is another kind of cooperation that has been done and I will use an example to explain.

At the time CIMMYT and Purdue were working heavily on opaque-2 corn, U.S.AID had funded Purdue with a contract to work on these problems and CIMMYT was also moving ahead very rapidly in this area. Since we had outside resources and CIMMYT had outside resources, we got together and worked very closely. This turned out to be a nice arrangement which does not always happen. It could well be that some University programs might mesh very nicely either with things CIMMYT is doing, or with developing country institution programs.

2. Collaborative Research Support Program

Another mechanism that, in my judgement, is still in the testing stages is the so-called Collaborative Research Support Program (CRSP) that has evolved. This is a very interesting mechanism. It is based,

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as you know, on the very important assumption that there is some set of problems in particular areas which are of common interest to agriculture in the United States and in the developing nations. This is the fundamental assumption underlying the entire CRSP mode. The corollary to this assumption is that through collaboration with scientists in developing countries and the international research centers, and which is jointly funded by AID and other donor countries, there will be complementarities which will benefit both U.S. and developing countries' agriculture.

This is an important concept, because in a very real way we are talking in these sessions about a similar kind of phenomena in which we try to join in an appropriate way research programs at our universities with those of CIMMYT, and with those of developing country institutions. It seems to me there needs to be that mutuality of interest if this is going to be a meaningful endeavor.

Consider the case of INTSORMIL, the Sorghum-Millet CRSP. The first problem, as many of you know, was whether or not it would be possible to take eight U.S. universities with some 80 principal investigators in those institutions and a very large number of collaborative scientists from abroad, and make that mechanism work. It was fairly well structured in terms of the management entity which happens to be at the University of Nebraska. In this capacity Nebraska essentially plays a service role, being the recipient and having responsibility for the money, providing the overall actors, such as program directors, and other administrative services. I think this a labor of love which is important for this particular type of mechanism to work.

The program structure in this particular CRSP model is a central management unit which essentially coordinates the entire program. There is a program director, and in most cases an associate director. These programs generally have a board of directors - an instructor in a sense - with a limited set of responsibilities; largely those of budget approvals, policy setting, resolving institutional disputes on occasion, and related activities.

The key to the INTSORMIL experience, in my judgement, has been the work of the scientists, organized in a series of technical committees, where the real input has come in terms of priorities for work that needs to be done. These have also evolved to provide an external evaluation panel which I think is a healthy thing to do. Some CRSP programs have had difficulties in making this work, but for the most part I think they are working well.

A CRSP is not the model we are talking about here, but I think there may be some CRSP experiences that may be useful as we work together to try to structure possible mechanisms which we need to make this type of program work.

3. Bottleneck Collaborative Research.

A third model is one that some of us worked on five or six years ago. The issue that concerned BIFAD and many of the IARC director generals is basically what Bob Havener presented before me. The mandate of the IARCs, having limited staff and resources, places them more in the applied research arena. Many of the Center directors then, and I presume now, believed their scientists were hitting some barriers which were really impeding progress of their programs, and they felt a real need to break through these. This was discussed among BIFAD staff, AID, and Center directors to determine whether there would be some way to develop a program mechanism to get some resources and people working on these vital issues.

Two people followed up on this; Floyd Williams, who is here, and Jim Nielsen from Washington State University. They spent a great deal of time working with the IARC staffs to identify their critical needs, some prioritization of these problems, and mechanisms to make it possible to do such important work. A proposal was presented which BIFAD accepted and approved, and AID approved, but that was about where it stopped. However, there are two or three things that I think we can use from this experience and which may be useful as we try to structure an institutional mechanism that will be necessary to support this kind of program.

ESSENTIAL ELEMENTS OF AN INTERNATIONAL NETWORK
FOR COLLABORATION IN MAIZE RESEARCH

Robert W. Kleis*

As we contemplate possible mechanisms for implementing international collaboration in maize research it appears to me there are a number of essential elements, for whatever type of mechanism evolves, that need to be considered; and which John indicated might be considered essential for whatever network system evolves for implementing collaboration.

1. A need and potential for effective collaboration. The summary discussions indicate that this essential element for maize is different from other commodities. With maize you have a much heavier research commitment by many institutions and organizations throughout the world providing a broader geographic distribution of that effort. So there would perhaps be more potency in collaboration here than with some other commodities.
2. Involvement of interested and competent scientists. This is essential and amply demonstrated by your presence and activities here during the past several days.
3. Involvement of appropriate agencies and entities. The very composition of this conference illustrates that we have attracted the heavy elements; U.S. institutions with major commitment to maize research, CIMMYT, U.S. Department of Agriculture, and selected developing nations.
4. Perhaps most obvious is the need for resources. In the early initiative for expanding collaboration particular attention needs to be given to making resources available to implement cooperative activities and especially for getting scientists together such as is happening here at this time.
5. Minimal bureaucratic complexity of whatever structure evolves and maximum responsiveness to scientific needs in collaboration.
6. The desirability of participation must be mutual for any collaborative relationship to be successful. I think sometimes our funding agencies tend to forget this. In the case of the CRSPs, we have to remind them of the need for mutuality of those participating.
7. A capacity to bring together scientists, such as is happening here, or more often in topic research groups; perhaps something similar to the six topic groups that existed here the last few days as panels for communication and sharing.

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Lincoln, Nebraska

8. The element of continuing communications of new programs, break-throughs, collaborative efforts which evolve, funding opportunities, and an active, continuing communication network through the participating scientists.
9. Technical and fiscal accountabilities to contributing sponsors and institutions.
10. Appropriate institutional endorsement of the collaborative activities. I know that many of you are professors and proud of your academic freedom, but you do need to have your institutional commitment behind you as you engage particularly in international activities. I'm sure that you are well aware of this and you will have no trouble if you get support beforehand. I would suggest that requests and proposals that are submitted to and through whatever structure may evolve need to involve a U.S. scientist as one of the elements of collaboration. There are other collaborative arrangements that are very productive, but here we are talking about a mechanism for involving the funding and the capabilities of the U.S. maize research community, and whatever may evolve here probably will be contingent upon a U.S. involvement in those relationships.
11. A minimally structured administrative mechanism probably at an appropriate institution which is willing to handle the administrative mechanics, perhaps without indirect costs, and provide fractional staff time of someone capable to provide the leadership. This unit will need to be supported by some kind of broad based panel or council with whom the coordinator can share blame for decisions. The entity in total, including whatever supporting panel may be evolved, will need to develop criteria and procedures and policies for operating the structure. One of the desirable elements would be the simplest possible authority mechanism in making decisions about supporting collaborators. Hopefully this could be vested in the administrative entity.

This leaves undeveloped and undefined the details of how such a structure might operate, but we need versatility and flexibility as we proceed to identify this mechanism. It seems to me that maize has a unique potential for much greater collaboration in research.

WHERE DO WE GO FROM HERE?
A PROPOSAL FOR CONTINUING COLLABORATION

Dale D. Harpstead*

There are three things that I think we need to remember and put up front in our thinking, and remind some of the people with whom we interact and many times must convince why we want to do the collaborative things which we talk about here today.

The Challenges Are Clear

We are all aware that vast numbers of people who desire maize for food exist in some state of need. Maize is a crop that can be profitably grown in an array of environments. Furthermore, it is a crop that has a variety of uses. It can significantly contribute to an improved quality of life and in some cases could become a cash commodity in their society.

The Opportunities are Great

Just as the challenges are great, so are the opportunities. The production of maize is one of the great success stories of this century and the body of scientific knowledge that has been built up around this crop is unequalled in the biological sciences. We realize, however, that this knowledge has not affected the lives of millions who struggle to harvest only a few kilos of maize where the potential for production is several thousand kilos from the same land area.

Appropriate Technology Must Be Adapted

I believe we have an obligation to see that the benefits of science and technology are more equitably distributed among maize producing societies. Even when the technologies are available, we know that people need to be prepared through education and experience to apply them to their own needs. We must promote the message that it is necessary to change if real progress is to be made. We can not achieve what people expect, and indeed have a right to expect, without change.

A vast body of knowledge exists about the efficient production of maize, but this information is largely location specific. Only in the last decade has any significant progress been made in the restructuring of this knowledge and its products to serve peoples in many parts of the developing world. The tasks that remain to be accomplished are unbelievably great. Programs need to be developed. New hypotheses need to be evolved and tested. New scientists need to be motivated, trained and supported. New information must be generated and disseminated, and new opportunities for scientific discovery and product development must be related in hundreds of locations throughout the world.

*Head, Crop and Soil Science Department, Michigan State University, East Lansing, Michigan

It is from the acknowledgement of sobering realities of world food production that we seek a mechanism to enable this assembled body to move forward and accept these challenges. By addressing these problems that remain to be solved in many maize production regions of the world, we believe we can assure the dynamic nature of this facet of the biological sciences so that all people, from developed and developing nations alike, will benefit from new findings and discoveries that will emerge. For millions of people these discoveries can mean an improved quality of life, if not life itself.

It is clear from our discussions this past week that cooperative efforts among scientists from U.S. universities, CIMMYT, and developing country maize programs could have significant value to all. Developing programs could profit from experience gained over several decades of scientific development. Where these have taken place, large resources in terms of laboratory instrumentation, libraries and so on can serve to back up programs where needed and would be readily available to solve problem situations that will emerge and that we know exist.

We know it is possible to train people and to help in the development of particular programs through the accumulation of information and its application. I believe that CIMMYT and U.S. universities will continue to gain from the extended environments in which maize could be challenged, tested, and evaluated. Present U.S. research on maize is estimated to be utilizing not more than perhaps 5% of the world genetic resources. The remaining 95% for the most part is the genetic resource that exists in the developing world. No one can say that the challenges are not clearly before us, or that we have solved these problems.

It is proposed, and I certainly endorse, that an action program evolve from this meeting. It should be a program that will facilitate linkages between scientists from developing country programs, CIMMYT, and U.S. universities. These linkages should result in scientific interchange, structured program development, problem-solving interventions, joint research endeavors, personnel development, and several more. I think these are indeed worthy goals. In many cases the costs of these cooperative efforts could be limited to costs of travel to get people together so that they can pool their expertise. In other cases joint program development requiring major investments and resources may be necessary.

To make possible the kinds of things that we have discussed here and which we would like to see take place, we propose that a committee be formed to represent us and our interests before U.S.AID, USDA, and other entities that may have similar program goals and objectives. This committee could be called upon to act rapidly, to be flexible, to function with dispatch as occasions demand, and certainly prepare themselves to promote and defend the recommendations that we have discussed here in general terms. For this purpose we have prepared a resolution to establish an Ad Hoc Work Group with a suggested mandate for your consideration.

DISCUSSION

John Stovall, Moderator

- QUESTION: Is there any plan as to what the Ad Hoc Committee is to accomplish?
- HARPSTEAD: I did make a first attempt to define the charge to this committee including suggestions made earlier. (See page .)
- HAVENER: When the panel considered what this committee might do, I think there was a general recognition it is unlikely a maize CRSP might come into existence without substantial new funding. However, this Ad Hoc Group might organize a "mini-CRSP" that would do some of the same things that the CRSP have done to facilitate cooperation from a group of U.S. universities with developing countries. It would have much the same purpose, but on a mini-scale rather than on the massive scales necessary to organize and mobilize resources for a CRSP. This committee could be the lead group to oversee that process until a more definite structure is brought into existence.
- HARPSTEAD: I could visualize opportunities to develop and continue linkages through travel support for scientists who had a valid reason to join forces with a scientist at another location in order to accomplish a particular task. I believe that would be the minimum place we might expect to start, although I hope it would only be a point of entry.
- QUESTION: Being neither a member of the university community nor an employee of CIMMYT, I would make an observation about this resolution and expect that there are good reasons for it to be as presented. There is no statement in the WHEREAS clauses regarding the function of CIMMYT* and it would seem entirely appropriate for one to be there; also, there is no inclusion on the ad hoc working group of anyone from the CIMMYT staff and this would seem similarly appropriate if this is to be a truly cooperative effort. I am sure you have considered these and that there are good reasons for it to be this way.
- HAVENER: I think you are quite right that the WHEREAS* and the purposes of CIMMYT probably should and could be included without any great difficulty. The reason for not having a CIMMYT representative may not make compelling rationale. Since the U.S. university community is organizing better coordination among themselves, with U.S.AID, with CIMMYT, and with Developing Countries, CIMMYT's role is perhaps better

*The "WHEREAS CIMMYT" clause was included in the proposal as approved -
Editors

served as an advisor to that process rather than as a party of it; but I am not sure this is compelling logic.

QUESTION: It was suggested in the summaries this morning that a very good way to get collaboration off the ground on a scientist level is to hold small mini-conferences in which a few people from the U.S. with direct concerns might meet here at CIMMYT in such areas as molecular biology and wide crossing, crop physiology, entomology, pathology, etc. I would like to move this specific recommendation as a way to get started if that is deemed appropriate.

STOVALL: I believe the thought of those working on this proposal is that this would be very appropriate action for the Ad Hoc Working Group, but that first we should put the working group in place without attempting to outline in too much detail the things they would do and presume they will consider and prioritize their activities. However, that would be consistent action in my view.

QUESTION: To foster the momentum generated here, these small groups should be meeting soon, say within 12 months. Can this committee, in the broad sweep that has been envisioned, facilitate such meetings within this time frame?

STOVALL: I think so. I believe these could be put into place almost immediately. However, I can only speculate as to how soon or even if they will have some money; but certainly it would be the intention to seek funding to support these kinds of activities. Of course, if such groups have funding from other sources then they don't really need this body to go ahead with their activities.

KLEIS: Certainly small groups getting together and working together is consistent with my concept of what might happen early on, but I also think that the working group needs to have convictions which are flexible to the signals we might get from potential donors.

ACTION ON RESOLUTION

The Conference membership unanimously adopted the following resolution establishing an Ad Hoc Work Group, and the charge for action.

R E S O L U T I O N

WHEREAS U.S. universities have the largest maize research program in the world, with a vast reservoir of scientific expertise in all phases of maize research, associated facilities, instrumentation and libraries, and

WHEREAS many of these Universities are also committed to assist in alleviation of world hunger through Title XII of the Foreign Assistance Act of 1975; and have many research and technical assistance activities underway in developing countries, and

WHEREAS CIMMYT is an International Agricultural Research Center funded by the CGIAR system for the purpose of increasing the productivity of maize and wheat, particularly in developing countries, and

WHEREAS the U.S. Universities - CIMMYT Maize Conference has identified numerous collaborative opportunities that could significantly benefit maize producers of the world, including the U.S.A., and

WHEREAS there is an urgent need to build on the momentum, enthusiasm and interest generated at this said conference and to follow up on its recommendations,

THEREFORE BE IT RESOLVED that conference participants endorse the establishment of an Ad Hoc Working Group to serve as a point of continuing contact for the community of interested maize scientists, further develop the various suggestions for collaborative research and devise a long term strategy for collaboration between U.S. Universities, CIMMYT and developing country scientists;

FURTHER BE IT RESOLVED that the organizer of this conference ask the following distinguished persons to serve on the Ad Hoc Working Group:

D. Woods Thomas, Purdue University - Chairman
Charles O. Gardner, University of Nebraska
Robert W. Kleis, University of Nebraska
Vernon E. Gracen, Cornell University
Earl D. Kellogg, University of Illinois
James C. Sentz, University of Minnesota

And the following distinguished individuals be invited to serve as advisors to the said Ad Hoc Working Group:

Roger L. Mitchell, University of Missouri
Ronald P. Cantrell, CIMMYT
Robert I. Jackson, AID
John Stovall, BIFAD

ADOPTED unanimously this 14th day of August, 1984 by the participants of the U.S. Universities - CIMMYT Maize Conference at CIMMYT Headquarters, El Batan, Mexico

CHARGE TO AD HOC WORKING GROUP

This working group should seek ways to move forward with prepared documents that capture the spirit of this meeting, i.e., the desire of scientists to be able to work cooperatively in solving the problems of maize production, protection and utilization, and that the message of this conference be brought before appropriate administrators who are in a position to facilitate these actions through funding and support. The message of our desire for joint action should also be communicated among the colleges and institutions of the Land Grant University System and other appropriate national and international research support systems, i.e., NSF, World Bank, etc.

This Ad Hoc Working Group should function until such time as a formal structure can be put into place. That structure, yet to be defined, should become a facilitating and coordinating unit designed to serve the needs of all participating persons and institutions.

COMMENT: D. Woods Thomas, Chairman of Ad Hoc Working Group.

I have been interested in this for many years. The maize program has some real potential, but was bypassed earlier for a variety of reasons. Timing now is not quite right moneywise to support a whole program. If we can find some funds to move ahead with a few of the things discussed this week, and if these turn out to be half as useful as we think they will be, then I believe that over time we can build the resources to do many of these kinds of things.

We will be looking to all of you to help us. We need to make this straight forward and as simple as we can. There is some urgency for funding to move ahead and we are planning to have the Working Group meet in one month, on September 14, to move as quickly as we can.

INTERIM REPORT TO U.S. AID



CENTRO INTERNACIONAL DE MEJORAMIENTO DE MAIZ Y TRIGO

INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER

Sede-Headquarters: El Batán, Tezcoco, Estado de México - Km. 25.5 Carretera México - Veracruz, Vía Jalapa
Correo Mail: Londres 40, Apdo. Postal 6-641, Col. Juárez Deleg. Cuauhtemoc, 06600 México, D. F.
Telex: 1772023-CIMTME Cable: CENCIMMYT Teléfonos-Telephone: México, D. F. 585-43-55; Tezcoco, 421-00

Dr. Nyle Brady,
Senior Assistant Administrator
Science and Technology Bureau
U.S. Agency International Development
Washington, D.C.

Through Dr. Robert Jackson

Dear Dr. Brady:

We deeply appreciate the support from the Office of Science and Technology which made the U.S. Universities - CIMMYT Maize Conference possible. Thank you also for your introductory remarks and active participation which were significant the first days of the conference.

We feel that the Conference was very successful. As proposed in our objectives, we did identify many areas for collaboration among U.S., CIMMYT and LDC scientists in maize research and training. The Conference participants also unanimously approved a resolution to establish a mechanism, seek essential funding, and implement such collaborative efforts.

The enclosed "Cost Effective Request for Collaboration" was prepared as an interim report on the Conference by several members of the "Ad Hoc Working Group" which was formed by resolution of the Conference participants (copy enclosed). This request is for your immediate information and consideration.

We are pleased to note that the Ad Hoc Working Group will hold its first meeting September 14 in Lincoln, Nebraska. The agenda for that meeting includes selection of several specific collaborative activities for immediate initiation. Enthusiasm is high among the Conference participants and several informal collaborations are already under way as a result of our meeting.

If you have any questions about this request or the Conference, please contact us. Meanwhile we look forward to your response.

Ronald P. Cantrell
Director
Maize Program

Sincerely,

James C. Sentz
University of Minnesota
Coordinator

A COST EFFECTIVE REQUEST FOR COLLABORATION
BETWEEN U.S. AND CIMMYT MAIZE SCIENTISTS

The U.S. Universities - CIMMYT Maize Conference held August 9-14, 1984, at El Batan brought together nearly 100 scientists from U.S. universities, CIMMYT and Developing Countries, who are engaged in all phases of maize research, to review ongoing research efforts and identify areas where collaboration offers the potential for a high payoff.

The conference identified a number of specific problems in maize breeding, germplasm preservation and utilization, diseases, insect/pest control, stress tolerance, protein quality, technology transfer, seed production, and related areas where a collaborative effort would greatly contribute to the solution of these problems.

Conference participants concluded that the collaboration they envisioned would require only a minimum of additional resources or redirection of effort on the part of either CIMMYT or U.S. scientists. For example, the collaboration might only require the exchange of material for testing; a visit by U.S. scientists to a CIMMYT Laboratory or Field Site; a workshop to plan or coordinate a research design or to interpret research data; or a meeting to share information about a new research technique. In most instances the additional cost of collaboration would be travel and associated costs of U.S. scientists.

The conference participants recommended an international network for this collaborative effort which would be based upon the following elements (or necessary conditions) for successful implementation:

1. Significant maize research with competent scientists in supported programs.
2. Enhancement of research efforts and utilization of results through increased international collaboration.
3. Involvement of U.S. universities and agencies, CIMMYT, and selected developing country scientists.
4. Resources for travel and workshops.
5. Mechanisms which would make possible rapid responsiveness to scientific needs.
6. Mutual benefit to each participant's program and institutional mission.
7. Workshop opportunities for interchange among scientists on a periodic basis.
8. Continuing communications of new projects, program inventory and collaborative linkages.
9. Appropriate institutional endorsement of collaborative activities.

10. Fiscal and technical accountability to grantors and institutions involved.
11. Requests and/or proposals for implementing collaboration which involve one or more U.S. scientists.
12. A minimally structured administrative mechanism at an appropriate existing institution or agency willing to handle the administrative services.

Because there are many potential collaborative activities and a large number of individual scientists and institutions involved, the Conferees concluded there was a need for some institution or agency in the U.S. to perform three primary functions:

1. Selecting the highest priority activities for support.
2. Coordinating and expediting collaborative research and training efforts.
3. Facilitating the flow of information among U.S., CIMMYT and LDC scientists.

The Conference took formal action in the form of a resolution (copy attached) to name an Ad Hoc Committee to work with CIMMYT, AID and other possible donors to implement this collaborative effort. The Committee, composed of Woods Thomas (Chairman), Charles Gardner, Robert Kleis, Vernon Gracen, Earl Kellogg and James Sentz, was specifically charged with:

1. Preparing documentation on potential areas for collaboration coming from the Conference.
2. Communicating the conclusions and recommendations of the Conference to appropriate administrations, scientists and organizations.
3. Coordinating efforts to implement the Conference recommendations.

Although the Conference did not attempt to prioritize numerous high-payoff areas for collaboration, several examples of areas identified for collaborative efforts follow:

- * Facilitate the development of improved seed production in targeted countries.
- * Address questions of maize collection, regeneration and evaluation as related to expressed concerns of gene loss and genetic drift.
- * Assess and evaluate the use of wide crosses as a source of specific characteristics having agronomic importance.
- * Formulate applicable procedures and evaluate CIMMYT gene pools and populations.

- * Identify effective procedures for inbred - hybrid utilization in support of national programs.
- * Review application of the "state-of-the-art" of genetic engineering for LDC utilization.
- * Develop an overall collaboration strategy and models for nutritional interventions which include QPM as a major component.
- * Plan and implement research on biological mechanisms controlling stress tolerance.
- * Apply recently developed virus identification techniques to the control of unknown virus strains for developing resistance and limiting their dissemination e.g., East African programs.
- * Adapt current crop-loss methods for on-farm identification and estimation of economic consequences of production constraints.
- * Develop practical methods and models for analysis of data, feedback to researchers, and development of recommendations from on-farm trials.

A P P E N D I X

U.S. UNIVERSITIES - CIMMYT MAIZE CONFERENCE

CIMMYT Headquarters, El Batan, Mexico
August 8 - 15, 1984

PROGRAM SCHEDULE

Wednesday, August 8

All day Arrival of Participants at El Batan
 (Note: Maize outreach staff arrive August 1)

18:00 Refreshments in the Guest House

19:30-20:30 Dinner in the Cafeteria

Thursday, August 9

All sessions are in the Auditorium unless otherwise noted

07:00 Breakfast in the Cafeteria

08:00 Welcome - Robert D. Havener
 Director General, CIMMYT

08:15 Opening Address - Nyle C. Brady
 Senior Assistant Administrator
 U.S. Agency for International Development

08:35 Welcome and Program Comments
 James C. Sentz, Coordinator
 University of Minnesota

08:50 Overview of CIMMYT Maize Program
 Ronald P. Cantrell, Director
 Maize Program, CIMMYT

09:20 I. Germplasm Preservation and Genetic Engineering
 Techniques in Maize Improvement - David C. Jewell
 Chairperson: Ronald L. Phillips

10:15 Coffee break. Outside auditorium. (Please hand in air
tickets at Travel Service desk near coffee service)

10:45 Group discussions on Topic I.
 Group A - Maize Conference Room 233, 2nd floor
 Group B - Board Room, main floor
 Group C - Maize Training Room 50, ground floor
 Group D - Wheat Training Room 32, ground floor
 Group E - Auditorium, ground floor

12:15 Lunch in the Cafeteria. Participants are invited to
take their trays to the Guest House terrace and into the
Rincon Mexicano.

U.S. Universities-CIMMYT Maize Conference, Page 2

Thursday (continued)

- 13:00 Group Reports on Topic I. Auditorium
- 14:30 II. Broad Base Gene Pools for Major World
 Production Areas - Hugo S. Cordova
 Chairperson: Charles O. Gardner
- 15:15 Coffee break, Outside auditorium (Please hand in air
 tickets at Travel Service desk near coffee service)
- 15:45 Group discussions on Topic II
 Conference rooms as designated for Topic I
- 17:20-17:45 Slide Presentation on CIMMYT's Activities (optional)
- 18:00 Welcome Reception in CIMMYT's Guest House
- 19:30-20:30 Dinner in the Cafeteria
 Rincon Mexicano open until 22:00 hours

Friday, August 10

- 07:00 Breakfast in the Cafeteria
- 08:00 Group reports on Topic II
- 09:00 III. Development and Improvement by Recurrent
 Selection of Populations Derived from
 Gene Pools - Shivaji Pandey
 Chairperson: Arnel R. Hallauer
- 09:45 Coffee Break, Outside Auditorium
- 10:00 Breeding Methods for Streak Resistance
 Magni Bjarnason
- 10:30 Group discussions on Topic III
 Conference rooms as designated
- 12:00 Lunch in the Cafeteria

U.S. Universities-CIMMYT Maize Conference, Page 3

Friday (continued)

- 13:30 Group reports on Topic III
- 14:30 IV. Quality protein Maize: Breeding, Nutritional
Aspects and Adoption - Surinder K. Vasal
Chairperson: David V. Glover
- 15:30 Coffee break, Outside Auditorium
- 16:00 Group discussions on Topic IV
Conference rooms as designated
- 17:30 Free Time
- 18:30 Refreshments in the Guest House
- 19:30-20:30 Dinner in the Cafeteria

Saturday, August 11

- 06:30 Breakfast in the Cafeteria
- 07:30 Field Trip to Tlaltizapan
Departure on buses in front of dormitories
- 18:30 Return from Tlaltizapan
- 19:00-20:30 Dinner in the Cafeteria

Sunday, August 12

- 07:00 Breakfast in the Cafeteria
- 09:00-12:00 Optional trips to (1) Pyramids or (2) Chiconcuac
Transport in front of dormitories departs at 09:00 hours
- 14:00-17:00 Buffet-Reception in Guest House Gardens
Conference Guests and CIMMYT Staff
Mr. and Mrs. Robert D. Havener, Hosts

Monday, August 13

- 07:00 Breakfast in the Cafeteria
- 08:00 Group reports on Topic IV
- 09:00 V. Characterization of Biological and Environmental Stresses and Development of Selection Techniques - Gregory Edmeades
Chairperson: Loyal F. Bauman
- 10:00 Coffee break, Outside Auditorium
- 10:30 Group Discussions on Topic V
Conference rooms as designated
- 12:00 Lunch in the Cafeteria
- 13:30 Group reports on Topic V
- 14:30 VI. On-Farm Research Programs for Maize -
Alejandro Violic, Arnold F. E. Palmer,
James B. Barnett
Chairperson: Margaret E. Smith
- 15:15 Coffee break, Outside Auditorium
- 15:30 Can the Success Story of Kenya Hybrid Maize Repeat
Itself in Nigeria - Yoel Efron and Soon K. Kim
- 16:00 Group Discussion on Topic VI
Conference rooms as designated
- 17:30 Free time
- 18:30 Refreshments in the Guest House
- 19:30-20:30 Dinner in the Cafeteria

U.S. Universities-CIMMYT Maize Conference, Page 5

Tuesday, August 14

- 07:00 Breakfast in the Cafeteria
- 08:00 Group reports on Topic VI
- 09:00 Training Opportunities and Possibilities
Moderator: Clyde E. Wassom
Panel: R.L. Paliwal and James C. Sentz
- 10:00 Coffee break, Outside Auditorium
- 10:30 Research Plans and Possibilities:
Reports of Topic Chairpersons
Moderator: James L. Brewbaker
- 12:00 Lunch in the Cafeteria
- 13:30 Organization and Structure for Collaboration:
Possibilities and Potential
Panel: Robert D. Havener
Robert I. Jackson
D. Woods Thomas
Robert W. Kleis
Dale D. Harpstead
John Stovall, Chair
- 15:00 Coffee break, Outside Auditorium
- 15:30 Summing Up
Ronald P. Cantrell - CIMMYT
James L. Brewbaker - Universities
Robert I. Jackson - U.S. AID
- 17:30 Adjournment - James C. Sentz
- 18:30 Refreshments in the Guest House
- 19:30-20:30 Dinner in the Cafeteria

Wednesday, August 15

- All Day Departure of Participants

CONFERENCE PARTICIPANTS

U.S. UNIVERSITIES

NAME And ADDRESS

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Agricultural Trade and Development
Farming Systems Research/Extension
International Research and
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Corn Breeding, Corn Genetics
Hybrid Seed Corn Production
Corn Production

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Tropical Tree Improvement
Biochemical Genetics

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Corn Breeding
Population Improvement
Qualitative Genetics

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Maize Breeding
Quantitative Genetics
Experimental Design
Forage Quality

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Maize Genetics, Physiology and
Breeding
Seed Science and Technology
Crop Simulation and Modeling

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Maize Breeding and
Quantitative Design
Breeding for Physiological Traits
Statistics

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Corn Breeding,
Recurrent Selection
Quantitative Genetics

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Nutritional Anthropology
Nutritional Impact of Agricultural
Technology
Farming Systems Research
Nutritional Concerns in
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NAME And ADDRESS

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Maize and Sorghum Pathology
Host Plant Resistance and Gene
Deployment
Breeding for Disease Resistance
Control of Field Crop Diseases

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Quantitative Genetics
Population Improvement
Germplasm Utilization
Genetics

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Genetics and Cytogenetics of
Maize Endosperm Mutants
Genetics and Breeding for Protein
and Carbohydrate Quality
Genetics of Transposable Elements
and Use in Gene Transfer

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Racial Studies of Maize
Maintenance and Utilization of
Maize Racial Collections
Isozyme Genetics of Maize
Maize Evolution and Breeding

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Plant Virology
Immunology
Plant Physiology
Plant Pathology

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Maize Breeding
Maize Genetics
Breeding for Disease and Insect
Resistance

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Corn Breeding
Population Improvement and
Recurrent Selection
Quantitative Genetics
Breeding Methodology

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Plant Stress Physiology and
Metabolism
Genetic Improvement of Crop
Stress-Resistance

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Genetics
Molecular Biology
Plant Physiology
Biochemistry

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SPECIALIZATION And INTERESTS

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Maize Breeding and Genetics
Maize Production and Utilization

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Corn Production
Soybean Production
Agronomic Statistical Analyses

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Soil Fertility
Plant Nutrition
Soil Fertility x Genetic
Interactions

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Grain Crop Production
Cell Culture Growth Herbicide
Activity
Plant Regulators

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Cytogenetics
Plant Genetics
Plant Breeding
Molecular Biology

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Maize Germplasm and Breeding
Maize Evaluation and Adaptation
Quantitative Genetics

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Genetics and Breeding for:
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White Endosperm Maize
Virus Resistance

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Plant Breeding
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On-Farm Research
Microcomputers in Agricultural
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Economics of Agricultural
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Agricultural Production Economics
Agricultural Development Process
International Development and
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Corn Insect Control
Insect Pest Management

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Tillage and Soil Management
Soil Structure

Herman L. WARREN
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Genetics of Host-Parasite
Interactions
Physiology of Maize Stalk Rot
Breeding for Disease Resistance
Biology of Soil-Borne Diseases

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Corn Breeding
Graduate Plant Breeding Courses
International Travel Study Program

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Evolution Under Domestication
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Host Plant Resistance
Graduate Entomology-Nematology
Courses

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Host Plant Resistance
Applied Corn Breeding
Quantitative Genetics

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I. GERMPASM PRESERVATION AND GENETIC ENGINEERING
TECHNIQUES IN MAIZE IMPROVEMENT

ISSUES

- A. Evaluation and Screening Techniques, Incorporation of New Introductions, Regeneration Procedures, Long Term Storage, and Distribution Protocol.
- B. Inter-generic and Other Wide Crosses for Transferring Genetic Variability.
- C. Which Aspects of Maize Improvement, Such as Nutritional Quality, Stress Tolerance, Gene Transfer, etc., Are Amenable to Genetic Engineering Techniques?
- D. Are There New Traits to Explore and Develop Because Genetic Engineering Techniques are Available?
- E. How Should New Bio-genetic Techniques be Integrated Into the Current Improvement Program, and What Will be the Position and Role of CIMMYT and Universities Toward Basic and Applied Research?

A. EVALUATION AND SCREENING TECHNIQUES, INCORPORATION OF
NEW INTRODUCTIONS, REGENERATION PROCEDURES, LONG TERM
STORAGE, AND DISTRIBUTION PROTOCOL

Moderator: Wayne L. Haag - CIMMYT
Rapporteur: David V. Glover - Purdue University

Our discussion primarily addressed evaluation and screening techniques. Discussion of other areas was in relation to evaluation and screening issues. The consensus of the group on these issues is summarized in three main points.

1. There is urgent need for information, summary and communication of data on the germplasm bank collections.
 - a. CIMMYT should be encouraged to continue efforts to complete the summarization and publication of information gathered some years ago.
 - b. Evaluations and information on collections available at other institutions and national programs should be included to make the data bank information retrieval more complete. Some conferees believe there is much unreported information available and that it should be brought together in a centralized catalogue.
 - c. There is expressed need for identification of a "lead agency" to manage maize germplasm bank material and information retrieval. There is confusion over the responsibilities, relationships and communication among groups such as the National Plant Genetics Resource Board, International Plant Genetics Resource Board, CIMMYT, USDA Plant Introduction and others.
 - d. There is need for more mandatory information retrieval policy for distribution germplasm bank accessions. Materials are provided to interested parties for evaluation, but very little information is reported to the information center at CIMMYT.
2. Evaluation is important and should be expedited. How and where CIMMYT and U. S. universities can collaborate in this was discussed in depth. It is our general opinion that this can best be done by screening for specific characters and many examples were suggested. If U. S. universities are to assume an active role in this process, a specific program must be generated with identification of funding to support the collaborative activities.
3. Collection of germplasm materials should continue, particularly in those areas previously unsampled or poorly represented such as the Highlands and Africa. Existing national programs should be encouraged to collaborate and actively participate in the collection and evaluation of their materials as a part of their program activities. In this way U. S. universities which are collaborating with other countries may also provide assistance and support.

B. INTERGENETIC AND OTHER WIDE CROSSES
FOR TRANSFERRING GENETIC VARIABILITY

Moderator: Richard A. Frederiksen - Texas A&M University
Rapporteur: Andrew D. Hanson - Michigan State University

Our discussion of this issue is summarized under four headings.

1. Can wide crosses research be justified?
There was much doubt expressed about whether available variation in maize is really limited since the primary gene pool (especially tropical maize germplasm), has not yet been adequately evaluated for traits of interest. Moreover, in the specific case of physiological disease resistance mechanisms, there is no evidence that genes incorporated via wide crosses have proven any more stable or enduring as sources of resistance than those genes that have come from within species crosses.
2. Which traits might be manipulated through wide crosses? (Assuming such traits are not already present in the maize gene pools).
Strong opinion emerged that wide crosses would be appropriate only when some definite trait was desired, and when that trait was readily identifiable and simply inherited. For complex traits such as drought resistance, wide crosses were viewed as a "fishing expedition" and considered inappropriate for CIMMYT since the chance of obtaining a useful product is very low.
3. The relationship of wide crossing to DNA transformation techniques.
Wide crosses of a conventional type are related to DNA transformation of pollen since the latter is essentially a "facilitated wide cross." Support and interest levels in the U. S. will continue to be much higher for critical research in DNA transformation than in conventional wide crosses. There is no difficulty, therefore, in identifying U. S. collaborators for DNA transformation work and it is appropriate to set up such collaboration with CIMMYT.
4. Education and training in advanced biotechnology.
New technologies based on advances in molecular genetics are emerging rapidly in plant breeding. It is therefore appropriate to expose plant breeding students to molecular genetics for both their education in mechanisms by which genes act, and their preparation for the future advent of new molecular level tools. However, there was great reservation expressed about training developing country students as molecular genetics specialists because of frustrations they are certain to suffer through lack of facilities and the basic irrelevance of molecular techniques for dealing with most agronomic problems in their home countries.

C. WHICH ASPECTS OF MAIZE IMPROVEMENT, SUCH AS NUTRITIONAL QUALITY, STRESS TOLERANCE, GENE TRANSFER, ETC., ARE AMENABLE TO GENETIC ENGINEERING TECHNIQUES?

Rappateur: Vernon E. Gracen - Cornell University

The consensus of this group concerning the applicability of genetic engineering techniques is summarized under six points.

1. Constraints to maize production that could be effectively studied with these techniques and approaches are:
 - a. Pest resistance including stem borers, fall army worms and viruses, and
 - b. Environmental stress tolerances such as drought, aluminum toxicity in acid soils, etc.
2. Problems that could be effectively studied at the molecular, cellular or tissue culture level include:
 - a. Tolerance to salts, herbicides, drought and pathogen produced toxins, and
 - b. Assessment of somaclonal variation as a means of creating useful genetic variation.
3. Alternative approaches to be considered for reducing maize production constraints are:
 - a. Species bridging through wide cross programs,
 - b. Manipulation of insects or pathogens to either control or eliminate damage, and
 - c. Molecular genetic studies of pathogens such as viruses to effectively define pathways and mechanisms of pathogenicity.
4. Several general concerns about genetic engineering are noted.
 - a. Many people expect genetic engineering to create new genetic diversity, but this may not happen in a heterogeneous crop like maize.
 - b. Publicity given to genetic engineering is encouraging developing countries to establish centers for such research. CIMMYT should serve as a coordinator in these developments to link U.S. institutions with such centers.
 - c. Funding for this research should be through NSF and comparable agencies rather than through industry or USAID.
 - d. Funding agencies should recognize the high risks associated with this research, and not expect significant applied results too soon.
 - e. Basic research in plant molecular biology should be supported because of the need for basic information, and not for expected short term benefits to agriculture which are unlikely to occur.
 - f. Basic research in genetic engineering should be done with currently grown varieties. CIMMYT should play a role in identifying such varieties.

5. There are major constraints associated with genetic engineering in maize.
 - a. Many traits of economic importance are under polygenic control and may not be amenable to gene transfer techniques.
 - b. There are no known vectors for genetic transformation for maize.
 - c. If genes can be transferred via genetic engineering, they may not be expressed.
 - d. Even if genes are transferred and expressed at a cellular level and followed by regeneration of plants, then extensive selection via traditional techniques will be necessary to recover agronomically desirable plant types.

6. Conventional approaches should be used to solve certain problems associated with increasing maize production.
 - a. Transfer of varieties and technology to farmers is a major obstacle in many LDCs, and should receive emphasis over genetic engineering.
 - b. Selection for homozygosity to identify and enhance the level of pest resistance could be just as useful as genetic engineering in the development of pest resistant varieties.
 - c. Conversion of day length sensitive maize races to day length insensitivity, such as is being done for sorghum, would allow greater distribution and utilization of germplasm bank materials, especially in the temperate zones.

D. ARE THERE NEW TRAITS TO EXPLORE AND DEVELOP BECAUSE GENETIC ENGINEERING TECHNIQUES ARE AVAILABLE?

Moderator: David W. Sperling - CIMMYT

Rappateur: L. Curtis Hannah, University of Florida

This group was in complete agreement that new technologies of molecular and cellular biology will be used to create and select for new traits within maize. Specification of such traits, however, is not possible at this time and the list would be endless.

Traits selected for manipulation through these new technologies in the future will be chosen in two fundamentally different ways. In one approach those traits will be chosen which can not be altered through conventional breeding techniques. In a second approach the traits to be altered will be chosen from an understanding of the underlying biochemistry and physiology and from characterization of the foreign gene to be inserted into maize. Most of our discussion focused on the first approach since knowledge needed to pursue the second approach is lacking for most agriculturally important traits.

Genetic engineering usually refers to two types of experiments. In one type foreign DNA is inserted by various mechanisms into the plant host. In the other type tissue culture and other techniques are used to create and select for rare genetic alterations.

DNA Transformation

Recent experiments in transformation of maize pollen with *Tripsacum* DNA are of particular interest. This initial observation should be pursued quickly to see if it is correct and molecular probes should be exploited to determine if differences observed in the resulting progeny are due to incorporation of foreign DNA. Other systems should also be pursued. The "Ti" plasmid should be explored as a vector for corn. Transposable elements of the maize nucleus as well as the small circular DNAs of the mitochondria should be examined. The use of naked DNA for transformation should be pursued.

The role of CIMMYT in this should be extensive testing for rare transformants. Current collaboration with the University of Illinois and Cold Spring Harbor Laboratories should be continued and encouraged with other U.S. universities.

In these transformation experiments only one or a few genes will be transferred. Thus the introduction of many genes to code for a new, complex biochemical pathway is not feasible. Efforts should be directed, therefore, at identifying single rate-limiting steps in biochemical pathways important for productivity so that these reactions might be altered by gene introductions. It should also be made clear that the introduced gene must be expressed in an orderly manner if its presence is to have any consequence. Thus studies on gene expression and isolation of closely linked regulatory sequences should therefore be emphasized. These studies will be just as important as the actual transformation experiments.

Tissue Culture and Plant Regeneration

A second approach is through tissue culture techniques. Two types of experiments are important. First, DNA transformation of single cells will be agriculturally important only if whole plants can be regenerated from single cells. Thus plant regeneration experiments should be emphasized. Second, tissue growing in culture can be used to screen for rare mutants. These experiments have two advantages; a large number of units can be observed, and there should be less variation in test tube experiments in comparison with field experiments. Tissue culture screening could be done for many traits. Any system whereby a toxic substance or some stress can be applied to the cells could be used. Obvious examples include disease resistance, acidity, and resistance to various herbicides. CIMMYT could play an important role in the screening of various tissues.

Non-Conventional Techniques

This group also considered a third class of experiments which we termed non-conventional genetic transfer utilizing genetic stocks not normally used by corn breeders. Cooperative efforts between the University of Missouri and CIMMYT in the use of TB-A translocations to uncover recessive alleles possibly conditioning resistance to various diseases were noted. The use of transposable elements to create greater variation within a small segment should be considered for the alteration of agriculturally important genes.

This group suggests that the extensive screening required in this research and the dissemination of information to other maize scientists should primarily be done by CIMMYT. Studies of gene structure, function and regulation as well as vector development and plant regeneration should most probably be done in U.S. universities. Interactions between CIMMYT and U.S. universities in this research such as that now in progress with the University of Illinois, should be highly encouraged.

E. HOW SHOULD NEW BIO-GENETIC TECHNIQUES BE INTEGRATED INTO CURRENT IMPROVEMENT PROGRAMS, AND WHAT WILL BE THE POSITION AND ROLE OF CIMMYT AND UNIVERSITIES TOWARD BASIC AND APPLIED RESEARCH?

Moderator: Alejandro Ortega C. - CIMMYT

Rappateur: Major M. Goodman - North Carolina State University

Discussions and recommendations on this issue are summarized under three headings.

Development of Bio-Genetic Techniques

Bio-genetic techniques need to be developed further before much practical application to monocots is possible. This effort may require another 10 years.

CIMMYT should annually host a competent, active leader in the field whose work directly impinges upon practical applications for one week of consultations and discussions. Ideally these individuals should represent different universities such as Berkeley, Minnesota, North Carolina State and Wisconsin. Some conferees suggested a resident expert should be employed, but others felt that such a person would be either wasted at CIMMYT without meaningful work, their expertise soon outdated, or both.

CIMMYT should have a direct interest in applied research, and in some cases basic research, results in the following areas.

1. Sensitivity to daylength, perhaps using the normal counterpart of the id allele.
2. Single cell screening methods for tolerance to stresses such as heat, drought, aluminum toxicity and herbicides.
3. Considerable scepticism was expressed by many towards the use of somaclonal variation based on negative results in other crops, most notably potato and analogous tobacco anther culture, but others regard it as a useful tool with pure line material.

Preparation for Utilizing Biotechnology

All CIMMYT germplasm stocks, i.e., individual collections, groups, composites, pools, populations and varieties, with first emphasis on individual collections which are most easily evaluated and the most likely sources of new traits, should be carefully evaluated for the following characteristics.

1. Adaptation to diverse, but commonly encountered environments including the following: equatorial low (below 1000 m) and intermediate (1800-2000 m) elevations; high, medium and low elevations at about 20° latitude with the medium and low elevations used in both summer and winter seasons. Only 5 to 10 plants per accession are needed per environment. Data should be collected for flowering dates, plant and ear heights, lodging, appearance of yield potential, and obvious susceptibility and resistance to diseases and insects. The adaptation data is a necessary prerequisite before other evaluations can be conducted.

2. Major potential fungal, viral and bacterial diseases
3. Major insect pests including earworms, armyworm, rootworms, various borers, and stored insect pests
4. Striga resistance
5. Drought tolerance, especially just before flowering
6. Heat and cold tolerance

Evaluations for 2 through 6 should be conducted under the most appropriate environmental conditions as indicated by results in 1 above. This should be done in collaboration with expert personnel from universities and the USDA.

Ideally, these evaluations should include all Latin American maize collections, perhaps 20,000 to 25,000 in number, and a reasonably appropriate set of sub-Saharan African collections, as well as the available accessions of teosinte.

This work could be coordinated by CIMMYT, but it is critical that other specialists be included. There should be either a single person or a committee with a strong chairman to initiate this program to keep the projects moving, publish the results, and ensure that all germplasm is screened.

CIMMYT and the Universities Should Be Prepared to Respond Promptly When Appropriate Biotechnology Becomes Available.

CIMMYT should retain its basic strategy of applied research and maintain an appropriate plant breeding staff with adequate support facilities.

The universities should emphasize basic research, with at least a core of applied work appropriate for training plant breeders and applied geneticists. Graduate training should include both basic and applied science. Graduate programs appropriate for U.S. industry are often quite inappropriate for LDC research and development, where the orientation is most often toward direct application.

The following issues were briefly discussed and significant points are noted.

Germplasm Preservation.

Proper regeneration, evaluation and long term storage should be initiated at once. At least 100 successful pollinations per collection should be the goal for regeneration. Long term storage of at least one kilo at -20° C should be maintained at 2 or 3 locations - CIMMYT, USDA, and Colombia or Costa Rica. Distribution should be from intermediate term (5°C, 25% humidity) storage facilities only. Regeneration and evaluation, in this order, should take precedence over acquisition. Acquisition priority should be to obtain suitable one kilo collections of teosinte at approximately 150 sites.

The USDA has a standing offer to financially assist CIMMYT in regeneration of all of its accessions, provided they will share samples of such seed increases in sufficient quantity for systematic evaluation. These samples would be designated for active use, with a portion consigned for long term storage at Fort Collins. Detailed plans for this evaluation, should include collaboration with CIMMYT, U.S. universities, and interested national programs. INIA in Mexico, ICA in Colombia, and PCIM in Peru (the other major New World maize germplasm banks) have agreed to jointly participate with the USDA in this effort.

Plant Breeding Research Strategy

Historically corn breeding developments in the U.S. and elsewhere suggest that certain general features may be appropriate to CIMMYT - U.S. university collaborative endeavors in both breeding and biotechnology.

Certain races, and indeed specific collections or populations, of maize are far more useful than many others of apparently equal preliminary promise. Examples of these are well known to most experienced international breeders. Compositing these across social and geographic lines obscures almost all possibility to scientifically determine which sources are truly useful, and the opportunity to examine their close biological and geographic relatives.

Maize breeders working with independently derived materials, but participating in common evaluation trials, have greater chance for success than they would working in lockstep, following a central authority and using only common breeding materials and methodologies. This point is probably even more applicable to biotechnology than to breeding.

Prior to selection in any population, it is most profitable to determine that the best possible materials for the desired traits are, in fact, in the population. If widely adapted varieties are wanted, then the materials to be composited should be widely adapted. There are reasons to seriously question whether maize can be developed which is as widely adapted as the successful wheats. Maize is monocious, and timing of male and female flowers is not nearly as readily synchronized as in wheat. U.S. breeders have been using shuttle breeding in Florida since 1950 and in Hawaii since about 1960 with little obvious increase in adaptation to tropical and subtropical environments.

Plant Breeding Assistance in Testing and Distribution.

Appropriate maize varieties and/or hybrids are available in most areas of the world, and if the better ones were used with good technology, production could be easily doubled. There is still a need, however, to identify appropriate varieties, composites or hybrids suitable for immediate use by farmers, and for short, intermediate and long term breeding use by local breeders. CIMMYT could be most supportive in these efforts by helping to test independently derived local materials, and by breaking local bottlenecks in distribution of useful materials and technology.

Since governmental seed distribution and production agencies are often bottlenecks in these efforts, CIMMYT should provide direct training for such people, including appropriate apprentice training with good private or public seed producers. Several private sector firms are logical possibilities, and both Illinois and Purdue have associated wholesale seed organizations.

II. BROAD BASE GENE POOLS FOR MAJOR WORLD
PRODUCTION AREAS

ISSUES

- A. Pragmatic Definition of World Environments and Genetic Characterization for Generating Basic Gene Pools.
- B. Utilization of Gene Pools in International and LDC National Programs and Alternative Procedures for Maintaining and Distributing Genetic Materials.
- C. Procedures for and Problems Associated With Incorporating Germplasm Bank Materials Into Gene Pools.
- D. LDC National Program Needs and Role in Gene Pool Maintenance.
- E. Basic Research Needed and Role of Developed Countries in Gene Pool Maintenance.

A. PRAGMATIC DEFINITION OF WORLD ENVIRONMENTS AND
GENETIC CHARACTERIZATION FOR GENERATING BASIC GENE POOLS

Moderator: William A. Compton - University of Nebraska
Rapporteur: Marcus S. Zuber - University of Missouri

After much discussion we concluded that it is a very complex problem to classify environments for altitude, temperature, latitude, total rainfall, rainfall pattern, soil type, and disease and insect incidence. At this time we question whether further definition of the various environments would benefit CIMMYT's ongoing worldwide testing program.

It was suggested that basic research be undertaken and that U.S. scientists with expertise in the areas of plant physiology, climatology and geography be encouraged to address this problem. If environments could be more specifically defined and classified it should increase the efficiency of worldwide testing programs. New techniques and instrumentation are becoming available that would be helpful in this effort.

Appropriate use of data accumulated by CIMMYT on yield trials conducted during the past 10 years was discussed. This data should be used to determine genotype by environment interactions to identify which environments may be "unique" for genotype performance. Cluster analysis has been tried without much success, but various modifications of the approach might be warranted.

B. UTILIZATION OF GENE POOLS IN INTERNATIONAL AND LDC
NATIONAL PROGRAMS AND ALTERNATE PROCEDURES FOR MAINTAINING
AND DISTRIBUTING GENETIC MATERIALS

Rapporteur: Richard A. Frederiksen - Texas A&M University

Currently there are 46 gene pools utilized at CIMMYT; 9 tropical highland, 12 tropical lowland, 8 subtropical, and 13 special (temperate and quality maize). These pools are very heterogeneous, and generally lack agronomic adaptation. For this reason they represent a major work commitment for national programs utilization. Generally greater progress can be made more rapidly by national programs working with populations. Pools therefore represent a backup source of genetic variability for traits not found in more advanced populations. Clearly, the utilization and development of pools by strong national programs would be in their own best interests, as well as CIMMYT's.

We believe opportunities exist for development of special pools, particularly those with disease, stress and insect resistance. However, considerable research into methodology for stress resistance should be developed concurrently. Opportunities for collaborative research between U.S. universities and CIMMYT on gene action, frequency and interaction may provide insight into developing and utilizing gene pools.

C. PROCEDURES FOR AND PROBLEMS ASSOCIATED WITH INCORPORATING
GERMPLASM BANK MATERIALS INTO GENE POOLS

Rappateur: James L. Brewbaker - University of Hawaii

The framework for this discussion was expanded to embrace all germplasm sources contributed to the pools. It was agreed that:

- Germplasm bank materials constitute the primary basis for most pools,
- Germplasm bank materials include only a very small proportion of accessions having "much to offer," and
- As the pools are improved, it becomes increasingly difficult to add anything significant.

We concurred that this is a logical time for transition in development of pools, from their treatment as useful varieties per se to their treatment as potentially useful germplasm reservoirs for specific traits. It is recommended that:

- Databases be developed indicating what these reservoirs actually contain, and
- Stress be placed on mini-reservoirs or "special pools" in which gene frequencies for selected traits (e.g., insect resistance) be greatly increased before (a) pouring them back into the pool, and/or (b) spinning them off solely into advanced studies.

It is also recommended that indexing be considered in the choice of materials from these "special pools," with less concern for yield than for high gene frequency for desired traits. We agreed that temperate germplasm can contribute much to the tropical pools.

Clear guidelines for collaboration on this topic between CIMMYT and U.S. universities did not emerge from our discussion, except for continuing current cooperation in evaluation of temperate pools and inclusion of specific U.S. materials in the temperate pools.

We identified some real problems in several areas:

- How important is yield of the pool, and how many cycles of selection are needed?
- How important is seed color of the pool? Could the time spent on yellow and white (monogenic) pool versions be better spent on intense selection for specific traits in the "special pool" populations? Would this encourage more collaboration from specialists outside of CIMMYT?
- How important is expansion of the extremely broad gene base of any pool, if many useful and notably polygenic traits are at extremely low gene frequencies?

At this point there was a general feeling that CIMMYT-U.S. university collaboration is desirable in gene pool development, and much more so in population development from these pools. However, there are serious pragmatic problems in such collaborations including:

- Day length sensitivity of most pools, and
- The pools are not a practical resource for temperate region breeding programs.

D. LDC NATIONAL PROGRAM NEEDS AND ROLE IN GENE POOL MAINTENANCE

Moderator: Larry L. Darrah - University of Missouri
Rapporteur: Clyde E. Wassom - Kansas State University

What Are the Gene Pool Needs of National Programs and Are They Being Adequately Met?

LDC representatives and CIMMYT staff in the group were asked this question. The following summarizes their responses.

- * A source of inbred lines. An example is the use of Pools 22 and 25 in Brazil.
- * Good tropical materials are needed.
- * Crosses involving pools such as Tuxpeno #1 which has provided selected short materials and downy mildew resistance.
- * Evaluation of combining ability has been done by some national programs.
- * Some pools are useful directly, but recurrent selection is generally necessary for adaptation to local situations.

In general, the existing broad base pools seem adequate for the needs expressed. An additional need is to develop pools resistant to major insect and disease problems such as earworms, fall armyworms, maize streak virus, and others. Several other points and concerns were noted.

Heterosis appears to be expressed when local populations are crossed to some of the pools. However, this is probably no greater than the heterosis which could be achieved from combinations of selections from within a given pool.

Concern was expressed that local cultivars may be introgressed into the pools, and that this product might not reflect the real potential of the pool as a source of desirable genes for that given area.

Land varieties may be maintained and used in some national programs as pools for line development and population improvement programs. In other cases national programs maintain their own pools which provide source material for their programs, and could be available for use as source material in other areas as well.

What Can U.S. Universities Contribute to Gene Pool Evaluation and Improvement?

Some institutions may be established to evaluate responses to specific diseases or pests. Other sites with low rainfall should be suitable for drought resistance screening of pools. In general, however, there do not appear to be many direct ways for U.S. university involvement. Indirectly, universities train scientists who, in turn, can evaluate gene pool responses in the home environments of their national programs.

What do LDC National Programs Contribute to Gene Pool Maintenance?

They have little direct involvement. In some cases, however, they do request and receive samples of seed. Some national programs do maintain their own gene pools.

What do LDCs Contribute to Advancement of CIMMYT Gene Pools?

National programs evaluate, select and return seed to CIMMYT for further evaluation and development. In some cases the CIMMYT pools are not maintained as "static" pools, but are evaluated and refined to improve resistance to insects and diseases and to fit particular environmental needs whenever possible.

It was suggested that information pertaining to these pools be summarized and published to make it widely available to all maize researchers. It would also be desirable to make available similar information regarding national program pools.

Variations in soils, available nutrients, acidity, aluminum toxicity, moisture, etc. were discussed and evaluation of the pools in response to these factors is recommended. LDC program evaluations would be most useful for these variables.

LDC national programs do need broad based pools as sources of genetic variation for their breeding programs. Although they generally are not involved in pool maintenance, they can play an important role in evaluation, utilization and advancement of these pools.

E. BASIC RESEARCH NEEDED AND THE ROLE OF DEVELOPED COUNTRIES IN GENE POOL MAINTENANCE

Rappateur: Harold Z. Cross - North Dakota State University

CIMMYT has spent much time and effort in developing and improving many broad based gene pools, and they should be commended for these efforts. The primary concern of this group was how to make these pools more valuable and useful, and how future pools can be efficiently created to achieve maximum usefulness. Our discussion touched on various other issues in this conference. A number of questions arose from this issue which will require more research to provide definitive answers.

Specific questions regarding the creation of new pools were targeted for future research as follows:

- How broad a base should new pools have?
- Should potential constituent populations be screened so that only elite materials are used to create pools with relatively high initial performance level?
- What criteria should be used for inclusion of material in a gene pool?
- Should combining ability and heterotic pattern be major considerations, assuming that the ultimate goal is to use these pools as sources of hybrid varieties?
- Should the very best materials be included irrespective of kernel type, and specific kernel types be selected out as they are needed?

With regard to both existing and new pools, the following questions were raised.

- Should the pools be open ended with new material being added periodically?
- If so, how do you determine which and how much germplasm to add?
- Should unadapted materials with genes for specific desirable traits be added?
- How should an original source population be maintained as a yardstick for measuring changes in the breeding value of the pool?
- What are the best strategies for maintaining and improving these pools?
- Should selection intensity for improving these pools be high or low?
- Are S_1 or other inbreeding selection procedures effective methods for screening out deleterious genes?

Concerning the role of developed countries, the group discussed research relative to efficient management of gene pools, training of scientists from LDCs in methodology for handling these pools, and some direct work on these pools such as screening for seed quality and seedling traits, including those for adaptation to minimum tillage methods.

III. DEVELOPMENT AND IMPROVEMENT BY RECURRENT SELECTION OF
POPULATIONS DERIVED FROM GENE POOLS

ISSUES

- A. Recurrent Selection Technology and Application for Developing Improved Populations Including International Progeny Testing.
- B. Role and Use of Inbreeding as a Tool for Pyramiding Favorable Genes for Yield and Agronomic Characteristics, Disease and Insect Resistance and Other Stress Tolerance.
- C. Breeding Procedures and Techniques for Disease and Insect Tolerance/Resistance.
- D. Improvement and Utilization Alternatives Within LDC National Programs.
- E. Improved Populations vs. Line and Population Hybrids, and Seed Production for LDC Production Programs.

A. RECURRENT SELECTION TECHNOLOGY AND APPLICATION FOR
DEVELOPING IMPROVED POPULATIONS INCLUDING
INTERNATIONAL PROGENY TESTING

Rappateur: William A. Compton - University of Nebraska

The group agreed that new emphasis in CIMMYT be placed on publication in refereed journals. We suggest that priorities of CIMMYT scientists be revised to include publication as a part of their scientific leadership and relationship with their fellow collaborators. There are two reasons for this: 1) It would allow other scientists access to the unique, high quality information on recurrent selection and other scientific works and methods such as the bazooka infestation technique for insects, and disease inoculation and selection procedures, and 2) it would give recognition and visibility to individual CIMMYT scientists and their collaborators.

Discussion centered primarily around recurrent selection technology. A complete analysis of family data should be made to show gains from selection, genetic variation, and genotype x environment interactions for each advanced population. Comparisons should then be made among these populations to determine the reasons for larger gains in some populations.

Questions were raised about introgression into already highly variable advanced populations and experiments were suggested to evaluate this practice. One or more comparable populations should be handled in the same way with and without introgression to test the validity of the method.

There were some misgivings expressed, but the group generally concurred that one or more selection indexes should be developed and carefully evaluated for potential use by CIMMYT.

B. ROLE AND USE OF INBREEDING AS A TOOL FOR PYRAMIDING
FAVORABLE GENES FOR YIELD AND AGRONOMIC CHARACTERISTICS, DISEASE
AND INSECT RESISTANCE AND OTHER STRESS TOLERANCE

Rappateur: James G. Coors - University of Wisconsin

As a preliminary note, the group found it useful to interpret "pyramiding" to mean the accumulation or stacking of favorable genes. Our discussion of inbreeding was also restricted to that which occurs in recurrent selection for population improvement. Accumulating favorable genes in homozygous lines was viewed as an inappropriate objective for CIMMYT.

Population improvement procedures employed by the CIMMYT advanced unit include visual S_1 family selection. Selected plants are selfed within full-sib (FS) families which have been selected in international yield trials. Plants from visually selected S_1 families within selected FS families are then used for recombination. It was noted that, at least in one instance, incorporation of multiple disease resistance via recurrent selection is being attempted. For population 34, in addition to the standard FS- S_1 procedure described above, comparable FS families are inoculated for H. turcicum in the Poza Rica nursery, and selfed progeny within selected FS families are inoculated for P. sorghi during the next growing season in the El Batan nursery. Disease reaction information obtained in these trials is then used to aid selection in the parallel population improvement program.

Several questions on breeding methodology were discussed. Theoretically, S_1 and S_2 selection may be more effective for improving agronomic performance and pest resistance. Inbreeding is effective for unmasking deleterious traits. There have been suggestions in the past that CIMMYT should employ more than one or two selection methods. Some traits may be more amenable to particular selection strategies, and the training function of CIMMYT may be better served by exposing maize breeders to an array of selection schemes. One alternative suggested is to replace FS with S_1 families for the international progeny testing trials. Recombination would be among S_2 families from selected S_1 families. Visual selections could be made among S_2 families within selected S_1 families.

Practical considerations, however, dictate the final determination of the selection method employed. It is emphasized that yield test conditions in the CIMMYT program vary widely. S_1 family performance would be more variable than FS families in response to extreme environmental variation, leading to greater genotype x environment interactions and more difficult data analysis. More importantly, it may not be possible to obtain the seed quantities necessary for wide-area testing with S_1 selection procedures, and cooperators are more able to relate to FS than to S_1 family performance.

Although S_1 or S_2 recurrent selection may be necessary in U. S. programs to increase resolution among genotypes, the broad base CIMMYT populations and diversity of global environments may allow effective FS

family selection in the CIMMYT program. Such procedures as parallel selection for multiple disease resistance, used for population 34, are probably useful additions to the standard procedures for accumulating desirable characteristics.

It was the strong consensus of this group that there is a lack of data which would rigorously document the genetic gains made in the CIMMYT pools, and it is difficult to find numerical or statistical support for some of the selection procedures. The use of closed versus open populations and pools requires further investigation. Collaboration between CIMMYT and U.S. universities in this area of data summarization and statistical genetic analysis is recommended.

C. BREEDING PROCEDURES AND TECHNIQUES FOR DISEASE AND INSECT TOLERANCE/RESISTANCE

Rappateur: Linda Pollak - Iowa State University

There are three questions which must be answered when considering breeding procedures and techniques for disease and insect resistance in the populations derived from gene pools.

1. Are the pools and populations adequate to meet needs of the LDCs?
2. Are the selection procedures appropriate?
3. What are the comparative advantages for U. S. universities, CIMMYT, and LDC national programs?

Adequacy of Pools and Populations

The CIMMYT populations are generally adequate to meet the needs of the LDCs at this time. It is not clear whether a particular variety should exist in two forms; one resistant to a specific pest in a specific area, and the other non-resistant for other places where the pest does not occur. Although isogenic varieties would not be difficult to maintain, their development would add more work and they may not be necessary. It is neither feasible nor desirable to have broad base populations resistant to all pest problems, since such broad base populations would not be the best adapted for specific countries or locations, or even for all locations.

CIMMYT provides intermediate populations that generally need to be fine-tuned through national programs for their specific pest problems. Some countries, however, do not have such program capability and CIMMYT and U. S. university assistance is needed. CIMMYT should develop the capacity to respond more quickly to major pest epidemics. Coordination among maize scientists in CIMMYT, U. S. universities and national programs would help CIMMYT and LDC scientists to identify and contact U. S. scientists for assistance. This coordination should identify areas of the developing world where U. S. and CIMMYT collaboration would be most appropriate.

Appropriate Selection Procedures

With past focus on increased yield, performance levels have improved. Emphasis should now focus on disease and insect resistance. The complementary contributions to production from improved varieties and cultural practices should be identified. Perhaps the need for better agronomic practices surpasses the need for greater genetic resistance in some cases. As long as farmer yields do not come close to those in research plots, and cultural practices do not contribute to disease and insect prevention, the need for improved agronomic practices is crucial.

Comparative Advantages Among Collaborators

There are comparative advantages for universities to respond to the present problems through basic research, training of scientists, and long-term institution building. Some areas of basic research that could be done in U. S. universities and that would have immediate application are:

1. Genetics and ecology of tropical diseases and insects
2. Investigations of pests for which no resistance has been found
3. Mass rearing techniques for tropical insects and ways to achieve epibiotic and epizootic levels of infection and infestation
4. Genetic resistance studies.

Some of these studies could be done as part of graduate training in which LDC students do dissertation research in their home countries. This would help the student to develop those skills necessary for working in their own environment, help the country through useful research directed toward local problems, and provide the advisor first-hand experience in problems of the student's country.

Collaborative efforts should be initiated among breeders, plant pathologists, entomologists, and virologists in U. S. universities to help solve tropical pest problems. Collaboration should also be initiated with scientists in U.S. universities with expertise in other areas such as tropical soils.

D. IMPROVEMENT AND UTILIZATION ALTERNATIVES WITHIN
LDC NATIONAL PROGRAMS

Rappateur: Larry L. Darrah - ARS-USDA and University of Missouri

Discussions of this issue are summarized in two parts.

Training and Support for Personnel in the Breeding Effort

1. Graduate level training is desirable, with a minimum of one visit by the major advisor to the trainee's home country to evaluate program development approximately 12 to 15 months following their return.
2. In-country trainees need 6 to 12 months on-job-training within an existing program before being put out on their own.
3. CIMMYT regional staff can render great assistance to newly trained researchers, especially in developing their professional confidence.
4. Expatriate staff on maize projects need to establish contact with regional CIMMYT staff to enhance cooperation and become familiar with other similar efforts in the region.
5. Encourage regional workshops at two-year or shorter intervals. Financial support may be necessary initially, and locations should be rotated among national programs.

Breeding Population Exploitation

1. Encourage use of regional variety trials coordinated by CIMMYT staff. Entries should include appropriate pools, populations, and experimental varieties as well as advanced material from national programs.
2. Quarantine restrictions may limit free exchange of germplasm. If necessary, breeders should make special inspected increases of populations for germplasm exchange, e.g., to certify freedom from diseases, such as downy mildew and Stewart's wilt, for shipment to African countries.
3. Evaluation of populations and varieties should be undertaken both on research stations with good husbandry and at sites similar to those used by small farmers.
4. Diallel crosses of local and CIMMYT populations would provide information on combining ability for yield and pest resistance for making rational decisions regarding introgression of germplasm.
5. Populations may be used in four ways: 1) directly by production units, 2) in recurrent selection schemes for improvement per se, 3) as sources for extraction of lines for hybrid or synthetic development, and 4) in conjunction with local populations in a combination of intra- and inter-population improvement that could result in an improved variety, the F_2 of a variety cross, and eventually topcross or traditional hybrids.
6. The mode of population utilization will initially be a function of the intended or possible distribution and production system.

E. IMPROVED POPULATIONS VS. LINE AND POPULATION HYBRIDS, AND
SEED PRODUCTION FOR LDC PRODUCTION PROGRAMS

Moderator: Willy Villena D. - CIMMYT

Rappateur: Roy G. Creech - Mississippi State University

The group identified the following subjects for analysis and discussion.

Seed Programs

1. Successful use of improved varieties, regardless of their origin or method of development, requires reliable seed programs to produce and deliver dependable seed to farmers in a cost-effective manner.
2. National seed program personnel must be technically trained in principles of seed production, maintenance, and marketing.
3. Commercial seed quality potential is under genetic control and can be improved through appropriate selection as efficient screening methods are developed. Improvement in genetic potential of maize seed quality can be implemented at the present time through evaluation of advanced breeding materials.
4. A coordinated effort is needed in seed program development and information transfer that convinces farmers of the value of good seed. Small subsistence farmers in developing countries generally do not have a good understanding of the value of improved seed. The product price structure may be such that a total program of fertilizer, pesticides, and good seed is not practical. The lack of adequate seed certification and control programs in some developing countries are significant constraints to the availability and use of good seed.

Maintenance and Integrity of Seed

1. Maintenance of the genetic composition and integrity of a variety, inbred line, or hybrid is essential if it is to be successfully utilized in production. A variety must be predictable and sufficiently uniform under standard environmental regimes.
2. CIMMYT has developed maintenance systems for open-pollinated maize varieties. Methods have been developed by others for maintaining inbred lines, hybrids, and some open-pollinated varieties.

Training, Scientific and Technical Assistance

1. CIMMYT, U.S. universities, and other collaborators can strengthen the technical knowledge of national program staff members for varietal maintenance and good seed programs by continuing emphasis on training.
2. Plant breeders from CIMMYT and collaborating institutions should assist in the development of seed program infrastructure in developing countries to increase the probability that new plant breeding products will become available to farmers on a cost-effective basis.
3. Research should be expanded on the genetic improvement of seed quality, vigor, and resistance to biological and physical stresses. CIMMYT and U.S. universities should collaborate to improve evaluation and screening methods to improve seed quality.

IV. QUALITY PROTEIN MAIZE:
BREEDING, NUTRITIONAL ASPECTS AND ADOPTION

ISSUES

- A. Methodology for Breeding Hard Endosperm Opaque-2 Grain
- B. Prospects and Problems in QPM Adoption
- C. Utilization of Quality Protein Maize
- D. Nutritional Aspects of Opaque-2 and Other Grain Types
- E. Seed and Production Problems Associated With QPM

A. METHODOLOGY FOR BREEDING HARD ENDOSPERM
OPAQUE-2 GRAIN

Moderator: Marcus S. Zuber - University of Missouri
Rapporteur: Donald T. Gordon - Ohio State University

Our group commends the CIMMYT Maize staff for their development of methodology for combining quality protein in hard endosperm (HE) maize grain with yields comparable to those of normal maize.

Our group discussed possibilities for collaborative work for the development of temperate-adapted H.E. opaque-2 (O_2) maize. Such material would allow for studies using the same genetic materials at CIMMYT and various U.S. universities. Cooperative possibilities which we discussed follow.

1. Modification of the maize gametophytic factor to allow production of seed with pure H.E. O_2 genetic material. The aim would be to achieve stability and penetrance of the gametophytic factor under various environmental conditions, genetic backgrounds and allelic differences. This would require parallel selection schemes in H.E. O_2 maize both with and without the gametophytic factor and comparisons between the C_0 and C_n cycles. U.S. universities have a definite interest in such cooperative work.
2. Development of a simply inherited modifier system to produce H.E. O_2 maize for use in the gene pool. This would be particularly important for hybrid and variety development by National Programs. Production of H.E. high lysine corn by LDC farmers will require a seed industry for supplying pure seed. Development of such hybrid maize varieties seems to be a natural development for such an industry. Hybrids would be expected to have greater vigor and more resistance to insect, disease and environmental stresses than open pollinated populations.
3. Improvement of dry milling properties (i.e., grit quality) and food preparation to maintain the quality of protein and achieve acceptability of the food product by LDC farmers.
4. Development of H.E. quality protein in green corn primarily for use by Asian farmers.
5. Development of resistance to seed rots (especially Fusarium) and aflatoxin contamination in storage.
6. Exploration of alternative methods for generating quality protein mutants. This will require identification of mutants capable of producing quality protein by means other than the O_2 gene. Examples are selection of high threonine mutants by cell culture methods, and other mutants through non-inhibition of the lysine pathway by normal feedback inhibitors such as methionine.

7. Investigation of amino acid composition of the various protein fractions, such as zein, of H.E. O₂ grain in comparison with normal grain.

8. Characterization of various zein genes in H.E. O₂ maize by producing and sequencing CDNA probes.

Finally, our group had some reservation about the stability of H.E. O₂ maize performance under the range of environments and cultural conditions in countries where quality protein maize has potential usefulness.

B. PROSPECTS AND PROBLEMS IN QPM ADOPTION

Moderator: James A. Deutch - CIMMYT

Rappateur: Edwin T. Mertz - Purdue University

Hard Endosperm QPM Production Problems

1. Contamination by normal pollen in farmer fields must be prevented.
2. Storage of QPM seed in the humid tropics is a greater problem than with normal seed. Insects grow and multiply faster in QPM. These problems should be less severe in cooler areas.
3. Aflatoxin contamination is always possible, and must be carefully monitored in QPM.
4. Grain yield of QPM varieties may never reach that of normal varieties in some locations. This will reduce its acceptance by local farmers.

Prospects for Hard Endosperm QPM Adoption

1. Guatemala is leading the way in widespread adoption of QPM. Large scale testing of QPM on coffee plantations (the INCAP Patulul Project) showed significant improvement in the growth of children receiving QPM when compared with controls receiving normal maize. It was concluded that the poorest farmers would receive the most benefit from using QPM as their major starch and protein source because they would have the least chance of supplementing their diet with other foods.
2. National Programs should be encouraged to promote widespread farmer adoption of QPM which would reduce the possibility for normal pollen contamination in the field.
3. In developing countries, both soft and hard endosperm types would be most beneficial if consumed directly by humans. However, initial use in some countries (e.g., China and Thailand) may be for animal production.

Soft (Floury) Endosperm QPM Production Problems

1. Consumer acceptance in the Andean area demands that the floury types used have an extremely large kernel; introduction of the opaque-2 gene reduces kernel size.
2. A major breeding effort will be required to increase the size of the floury-1, opaque-2 kernel.

Prospects for Soft Endosperm QPM Adoption

1. There is a big advantage in not having to convert floury-1, opaque-2 kernels from the floury to the hard endosperm type.
2. A genetically engineered high lysine single gene could solve the problem of small kernel size.

C. UTILIZATION OF QUALITY PROTEIN MAIZE

Rappateur: Kathleen M. DeWalt - University of Kentucky

Several issue-areas emerged in our discussion of Quality Protein (high lysine, high tryptophan) Maize utilization.

Dietary and Nutritional Utilization

Three potential areas of dietary and nutritional utilization were discussed with specific issues for each.

1. Direct human consumption
2. Ingredient in mixtures, such as bread, replacing other and often imported grain
3. Livestock feed

Several issues associated with use as a basic grain for human consumption were discussed.

1. How is QPM used in comparison with normal maize?
We did not discuss methods of use in detail. It was pointed out that in some communities maize may be the only food available at certain times of the year and QPM may therefore be especially desirable for these situations.
2. How do consumers perceive QPM preference? How is grain quality perceived for producing traditional foods?
Studies done in Los Angeles suggest that modified QPM produces an acceptable product which is preferred by some. No information is available to us on the acceptability of other products. However, methods of testing preference are available.
3. What is the quality of protein after processing into traditional foods? Testing effect of traditional processing techniques on protein quality using QPM may be desirable. Many processing techniques, however, are known to affect nutrient content and especially amino acid balance.

The nutritional impact of breeding for Quality Protein was discussed. Several persons pointed out that in most diets producing protein-energy malnutrition, energy is the limiting nutrient. A normal maize diet sufficient for the energy needs of adults will also fulfill their protein requirement. For children, however, the situation is somewhat different and either higher quality protein, or more concentrated sources of protein are desirable. A primary limiting factor of a maize based diet in child nutrition is that the bulk required to meet energy or protein requirements is more than a child can consume.

If energy requirements are not fulfilled, then protein, irrespective of its quality, will be converted for energy. It was suggested that diets which would most likely benefit from QPM are those that have an abundance of energy provided by a low protein root crop (e.g., cassava) and supplemented by maize as a protein source. Others raised the question of

whether QPM was the least cost method to provide extra protein. Perhaps the intercropping of legumes would be a more economical and useful source of protein.

In breeding for nutritional quality, there was disagreement within our group on a number of issues related to diet characteristics and nutritional status. Further research will be required to solve some of these issues.

1. U.S. universities are already collaborating in nutrition research in Mexico, Kenya, and Egypt. A nutrition CRSP to study the effects of marginal malnutrition is generating information on the importance of specific limiting nutrients.
2. U.S. universities can contribute to the identification of preferred grain characteristics for production of traditional foods and the acceptability of QPM materials.
3. University expertise is available for assessing benefit/cost relationships of alternative protein sources including QPM.
4. U.S. universities could effectively collaborate in identification of target populations having specific dietary problems for targeting QPM programs.

Production Utilization

Modification for grain quality and selection for yield are proceeding at CIMMYT with success. However, some doubts were expressed concerning yield and yield loss through introduction of opaque-2. In isogenetic line comparisons opaque-2 appears to lower yield 10% to 15%.

Maintenance of opaque-2 in populations without loss of quality requires monitoring of proteins. This assay of protein quality requires laboratory facilities and its value to national programs utilizing opaque-2 is questioned relative to the magnitude of potential loss.

The amount of loss in post harvest storage needs more evaluation. It was noted that when granary weevils are introduced into normal maize and QPM, these insects benefit from the marginal nutritional quality of the QPM and multiply 10 to 14 times more rapidly than in normal maize. This emphasizes the need for improved storage for QPM materials.

There is a need for work on maintenance of the O_2 gene in populations both in farmers fields and in national programs. CIMMYT personnel suggest a need for basic research on the nature of modifying genes and their inheritance. U.S. universities can collaborate in this and in work on the gametophytic effect as a potential solution to isolation problems.

There is need to identify simple inexpensive procedures to determine protein quality that could be used for monitoring QPM in developing country programs. It was suggested, tongue-in-cheek, that granary weevils might be used as a bio-assay for this purpose.

Several persons noted that the disastrous experience with opaque-2 materials in the U.S. cornbelt in the 1970s has made many researchers wary of pursuing this research. If collaboration is to take place there would be a need to acquaint U.S. researchers with the current modified versions of QPM. Some members of the group question whether there is in fact a

market for QPM, either economically or nutritionally, for small farmers or larger commercial farms.

The use of QPM as an animal feed was briefly discussed. Dr. Li noted there is some interest in QPM in China as feed for swine. He did question whether other sources of lysine, e.g., synthetic lysine, would perhaps be more cost effective.

D. NUTRITIONAL ASPECTS OF OPAQUE-2 AND OTHER GRAIN TYPES

Rappateur: Dale D. Harpstead - Michigan State University

It was noted that a large number of genes are known to exist which, in one way or another, affect the chemical compositions of endosperm proteins. There does not appear, however, to be significant continuing scientific interest in the genetic effects of characters other than opaque-2, and no nutritional evaluations of effects other than those of opaque-2 are known to be in progress.

Several questions were raised relative to the effect of preparation (cooking) on the nutritional quality of products produced from QPM.

1. For some products the maize flour is from degermed kernels, i.e., arepas in Colombia as contrasted to tortillas in Mexico. This factor will influence the ultimate value of the product since the germ makes a valuable contribution to the protein content and quality.
2. Presoaking in quick lime for pericarp removal may influence the lysine availability and needs to be examined in controlled experimentation.
3. It was noted that cooking temperatures of the traditional maize preparations are generally low and are usually not considered to be a serious factor in lysine digestability and uptake.

Major discussion focused on the ultimate usefulness of QPM, and the proportions to be targeted for animal feed and for human consumption. It is our general consensus that, putting the emotional issues of human starvation aside, the major target use is likely to be for animal feed.

1. China with a huge swine population could greatly increase meat production efficiency by using a lower cost lysine source in animal diets.
2. It is government policy in the Dominican Republic to support a rebirth of its swine production industry. A part of this support program is the production of superior quality maize as feed for this industry.
3. Panama is cooperating with the Dominican Republic in the production and release of QPM hybrids and varieties.

4. Guatemala is attempting to move QPM into its markets at the same price levels as normal maize. It is believed that this will encourage the use of QPM in animal feeds.

Several possibilities for the development of products for human consumption were also discussed.

1. It was noted that if no yield disadvantages are experienced and if the physical characteristics of the grain are acceptable then there is no reason why QPM should not be introduced and accepted as a matter of course.
2. In countries that must import wheat, mixtures of up to 30% maize flour can be blended into wheat flour for bread production. The use of QPM in this process could be a cost effective and nutritionally advantageous alternative.

Concern was expressed relative to the problems of maintaining the genetic purity of QPM once it is in commercial production. What would constitute "tolerable" levels of purity, and what methods would be the most cost effective for maintenance of acceptable levels of genetic purity? The use of gametophyte factors to provide genetic isolation is a fertile field for research.

1. Some 20 to 30 such factors are known.
2. Better techniques are needed to evaluate these factors.
3. Most of these factors have not been studied and therefore should not be prejudged on the basis of limited research.
4. There is a question whether the better research investment is in the development of better seed programs in countries utilizing QPM, or in systems for the utilization of gametophyte factors to provide genetic isolation.

We generally agreed that programs for the utilization of QPM should be viewed as part of a total nutritional strategy. The following considerations are considered important to this strategy.

1. Is it logical to believe that QPM can be produced and maintained in production at no increase in cost as compared to normal maize?
2. How many eggs should be placed in the QPM basket?
3. It will be important to consider the relative returns from investments in calorie production per se, mixtures of foods to enhance diet quality, and the importance to diet acceptance and diet expectation for nutritional well being.

Possible future roles for U.S. universities collaboration and input are:

1. Basic research in the maintenance of purity and nutritional quality in production seed stocks, and particularly research in factors providing genetic isolation.
2. Training of personnel for the development and operation of laboratories to monitor QPM in areas of production.
3. Models of study for relative effectiveness of nutritional intervention strategies which include QPM and/or normal maize in food mixtures.

E. SEED AND PRODUCTION PROBLEMS ASSOCIATED WITH QPM

Moderator: Sutat Sriwatanapongse - Kasetsart University
Rapporteur: Dale N. Moss - Oregon State University

Our discussion was focused on two questions.

1. Are there unique problems in producing QPM as a crop?
2. Are there unique problems in producing and storing seed of QPM?

The answer to question one is generally "no." QPM can be produced, harvested, stored, and utilized much the same as "normal" maize. This view is supported by data presented by Vasal indicating that QPM containing the O_2 gene plus modifiers was equivalent to normal maize in yield, drying rate, storability and other important traits.

The QPM available from CIMMYT is not adapted, however, to all countries. For example, the best QPM available in Thailand yields only 80% of adapted, improved varieties. Significant improvement must be made before QPM will be adopted by their farmers. Attempts to encourage industry to offer a price incentive for QPM and to promote its use among farmers were both unsuccessful. The answer to question one therefore, is no only if the yield and storage characteristics of QPM are equal to normal maize.

Since CIMMYT populations are not adapted to many environments and since many developing countries do not have the capability to adapt these QPM populations to their conditions, CIMMYT should determine if they have the capability and resources to develop populations adapted to specific environments. This question applies particularly to several countries in Africa.

The answer to question two is also "no," although somewhat equivocally. If the QPM yield is equal to the normal, as was true for the O_2 plus modifiers lines shown by Vasal; if ear rot susceptibility is not greater than the normal; and if drying rate of the grain is equal to the normal; then production of seed of QPM should not be more complex than with normal maize. There was considerable uncertainty within our group, however, on the fate of lysine in genetically contaminated QPM. Lacking any specific data on this issue, we concluded that one way to solve this problem, and several other seed related issues, would be to produce and distribute only hybrid seed.

The issue of acceptability of QPM in the marketplace was also discussed. We concluded that QPM would likely be acceptable to most users, and the problem lies primarily in the lack of supply.

Some members of the group believe that QPM would best fit into many distribution channels if it were handled as a specialty crop, such as is done with waxy or amylo maize. Others see no particular problem in handling QPM the same as normal maize in the marketplace. An example was

cited of QPM grown in Central America where genetic contamination and other production problems do not appear to be more difficult than with normal maize crops.

We had the least consensus on the issue of QPM susceptibility to storage diseases and insects. Concern was expressed that fungi appear to be a greater problem in QPM storage than in normal maize. Some believe that certain insects prefer and will infest QPM more readily than normal maize. Others in the group placed these concerns in the area of myths. The argument was made that after 4 to 5 backcrosses there should be very little difference between QPM and the normal maize for most traits, including susceptibility to insects and storage diseases.

This latter discussion led to a general agreement that resistance to storage insects was inadequate in all maize materials, and the group suggests that CIMMYT increase its total effort on this particular problem. We identified this as an area where CIMMYT and the universities could collaborate effectively to the benefit of all.

Finally, the ultimate question asked was "When will CIMMYT drop work on normal maize and convert its entire program to QPM?" If QPM yields equally and can be handled like normal maize, but is superior in nutritional quality, then why continue work on normal maize?

V. CHARACTERIZATION OF BIOLOGICAL AND ENVIRONMENTAL
STRESSES AND DEVELOPMENT OF SELECTION TECHNIQUES

ISSUES

- A. **Future Directions and Needs in Developing Drought Tolerance.**
- B. **Future Directions and Needs in Developing Disease and Insect Pest Resistance, and in Using New Technologies for Disease and Pest Control.**
- C. **Selection Index vs. Single Criteria for Improving Stress and Pest Tolerances.**
- D. **Breeding for Biomass Production vs. Increased Harvest Index.**
- E. **Utilization of International Testing in Breeding for Biotic and Environmental Stress Resistance.**

A. FUTURE DIRECTIONS AND NEEDS IN DEVELOPING DROUGHT TOLERANCE

Moderator: Thomas Stillwell - Michigan State University
Rapporteur: Emerson D. Nafziger - University of Illinois

There was general discussion on the advisability and merits of selection for drought tolerance under natural conditions. This has worked well in a number of cases, but has not always been efficient. Regardless of the risks in having effective selection only when good locations are used, there was a consensus that selection under natural drought conditions is a practical approach. Limitations such as high variability and sometimes low heritabilities were mentioned.

Although morphological aspects of drought tolerance have been described, it is clear that there is little understanding of the biochemical and physiological mechanisms for drought tolerance. Such investigations would be very useful.

There is also little understanding of the genetic mechanisms involved in drought tolerance. Prolificacy appears to be associated with drought tolerance and should be a priority in selection for this trait. Beyond this, identification of the most efficient selection schemes will require further genetic study.

The group was in general agreement with Edmeades' proposed approach to breeding for drought tolerance. This approach includes development of a drought tolerant ideotype, possible specific locations IPTTs, selection for prolificacy, selection for drought tolerance in other CIMMYT populations, and divergent selection in order to document changes associated with tolerance. Additional suggestions by the group include the examination of alternative methods (e.g., high density and defoliation) for inducing stress, and the use of gametophytic screening techniques such as pollen dessication tolerance.

The group also agreed with Edmeades' suggestion for potential collaboration between U.S. universities and CIMMYT. These include 1) the development of a stress inventory for maize in the tropics, 2) research in areas such as the physiological basis for stress sensitivity, and root function and morphology, and 3) the development of screening methodologies. Our group added to these the need for training of scientists at post-graduate levels.

B. FUTURE DIRECTIONS AND NEEDS IN DEVELOPING DISEASE
AND INSECT PEST RESISTANCE, AND IN USING
NEW TECHNOLOGIES FOR DISEASE AND PEST CONTROL

Moderator: Richard A. Frederiksen - Texas A&M University
Rapporteur: Dale R. Hicks - University of Minnesota

Our group concurred that CIMMYT has done an excellent job in their current program of pest identification and breeding for resistance. This work should continue and resources should be made available to provide for more rapid progress.

The following areas were identified for collaborative work between U.S. universities and CIMMYT.

1. Techniques. Current techniques have led to increased plant resistance and/or tolerance to pests, but opportunity and need exists for additional improvement. Techniques are being improved continually. There are areas, however, where procedures need to be developed such as measuring and quantifying temperature and drought stress and in relation to biotic stresses.
2. Mechanisms of resistance. More rapid progress could be made in breeding for resistance to disease and insect pests if the mechanisms and systems of resistance/tolerance were better understood. Progress in developing resistance to pests has been good, but longer term and continued resistance should be possible if we had a greater understanding of mechanisms. The Cornell/CIMMYT entomology work was cited as a very good collaborative model. Opportunities exist and should be pursued to characterize plant pathogens in different host resistance strategies. Evaluation of host resistance by different techniques, and particularly those utilizing rate limiting systems, represents a fruitful area for collaborative work.
3. Economic losses to pests. These have not been well defined. Models for crop loss should be developed and improved to assess these losses in the tropics. Storage losses to insects and diseases need to be documented. The control or reduction of mycotoxins is an example where basic research is needed, as well as on improved storage conditions.
4. Biological control. The lack of available pesticides and their safety in developing countries increases the need for research and development of biological control methods.
5. Interaction of pest and physiological stresses. The effects of drought stress along with various diseases and insects and their interaction needs to be evaluated.
6. Costs of production. Production costs need to be determined to better identify technologies that will lead to more cost effective production practices.

7. Polycropping systems. Cropping systems can and do affect disease and insect pest infestations. These direct effects and their interaction need to be better quantified.
8. Virus identification. New techniques developed in U.S universities for virus identification are available to workers worldwide.
9. Physiological research on plant senescence. Can healthy stalks and roots be maintained to prevent invasion by low order parasites without sacrificing yield? What is the effect of plant pathogens on root development and efficiency, and host senescence? What is the system, efficiency and duration of translocation? A better knowledge of these fundamental questions is needed to improve the efficiency of the maize plant.
10. Other environmental stress. Competition from weeds has not been well addressed. Herbicides are not used and labor may not be available for weed control.
11. Agronomic production. Research to integrate all facets of production should be done to determine appropriate technology that can be adopted by farmers to improve yields. Pest control should be integrated as much as possible with these systems.
12. Documentation of pest problems. The major insect and disease pests should be documented by geographical and ecological regions.

C. SELECTION INDEX VS. SINGLE CRITERIA FOR
IMPROVING STRESS AND PEST TOLERANCES.

Rappateur: David M. Van Doren, Jr. - Ohio State University

Criteria for plant selection is dependent upon several factors including: 1) a single or multiple index, 2) kind of material such as pools or inbreds and 3) plant traits such as stress, pests, or some combination of traits.

These will likely be so specific to the problem, (such as a specific pest species or type of stress), that a generalization as to which is better appears futile.

Research is needed on the following to establish which selection index may be most useful, and for which conditions and purposes.

1. The relative magnitude of problems afflicting a given area and the order in which the problems are manifested.
2. The mechanism of genetic control of tolerance to the chosen pest or stress problem.
3. The genetic control of physiological and morphological characteristics which are deemed important in the susceptibility and control of the chosen pest or stress.
4. Determination of genetic control for easily and rapidly measured plant characteristics.
5. Quantification of the relationships between the expression of measurable plant characteristics and the desired plant products, such as yield, quality and yield stability, as influenced by measured levels of the pest or stress.

U.S. universities and institutions in developed countries are well suited as a class to collaborate with CIMMYT in these studies. CIMMYT should provide guidance in setting priorities for addressing these problems based on their worldwide experience. LDC national programs can provide CIMMYT with appraisals of magnitude and extent of perceived problems, and of possible selection criteria based on observations under their conditions.

In selecting U.S. collaborators for this work, consideration should be given to the following:

1. Collaborators should be capable of reproducing and controlling the range of environmental conditions encountered where the problem exists so that the specific pest or stress can be imposed along with other environmental conditions. Most U.S. programs could handle those requirements for problems amenable to laboratory study. Greater care needs to be exercised in selecting collaborators for problems to be studied in the field.
2. Field research should be conducted, if at all possible, where problems arise to better assure real world expression of the problem and associated environments. A good example is the Sahel

for drought; it has the accompanying heat not found in Colorado, which otherwise might be an excellent location for drought studies on a large scale.

A symposium convened with a limited number of persons carefully screened for competence, interest, and possible resources would be an effective mechanism for defining and establishing collaborative research. This would provide for an exchange of information, identification of specific research needs, and development of plans for attacking these needs. Potential symposium topics would be drought and soil fertility stresses combined, radiation stress, temperature stress, and striga parasites among others.

Some concern was expressed about other considerations not directly related to our topic which may influence CIMMYT's research priorities.

1. Are we perhaps pushing maize into non-adapted areas, which makes solutions to many problems much more difficult than for more adapted environments?
2. Could someone, and not necessarily CIMMYT, better spend resources to introduce other crops which may be better adapted than maize, and educate the populace to accept the substitution?

D. BREEDING FOR BIOMASS PRODUCTION VS. INCREASED HARVEST INDEX

Moderator: Eugene J. Kamprath - North Carolina State University
Rapporteur: Charles G. Poneleit - University of Kentucky

Biomass and harvest index were defined and the status of current knowledge of temperate and tropical germplasm was discussed. Generally biomass data are minimal and from recent temperate maize literature. Harvest index generally ranges up to 0.60 for temperate germplasm, and from 0.35 to 0.50+ for tropical germplasm. The results given by Edmeades in which biomass remained unchanged and harvest index increased as shorter plants were selected suggests that specific selection for harvest index in tropical germplasms may be useful.

The growth rate, growth duration and harvest index of tropical germplasm in the CIMMYT bank were discussed by Islam. He emphasized that the later maturing tropical populations showed greater positive associations of harvest index with improved yield than the earlier populations. The group suggests special attention be directed towards definition of growth rate observations since variables measured on individual plants are not the same as the variables measured on plant communities observed on a unit area basis.

Direct selection for harvest index may be tremendously labor intensive. It was suggested that perhaps the ability of the plant to efficiently distribute photosynthate could be readily assayed by examination of standing plants only. Such plants would have already successfully partitioned enough growth substrates to the stalk to adequately support an increased grain yield.

It was also suggested that plant ideotypes be developed for tropical plants as was done by Mock et al. for temperate maize at Iowa State University. Some desired qualities are (a) standability, (b) shorter plant height, (c) types adapted to both mechanized and subsistence culture, (d) stay-green characteristic to promote high yield, (e) long effective grain filling period, and (f) prolificacy to avoid barrenness and eliminate sink limitation.

The group discussed possible areas of cooperation between CIMMYT, U.S. universities, and national programs. Since many of the physiological traits discussed are only tentatively associated with yield and might require further definition of convenient selection procedures, it would seem appropriate to concentrate the major portion of U.S. universities cooperative work with CIMMYT headquarters where broad expertise and facilities are most adequate. Specifically, U.S. universities and CIMMYT should cooperatively evaluate CIMMYT and temperate germplasm for useful physiological traits, and devise appropriate selection procedures. Graduate student training would be an appropriate avenue for exploration of such traits. CIMMYT germplasm seems quite variable and would provide ideal study materials.

Among other physiological traits, the brachytic "dwarfing" genes were suggested for study in tropical climates. Although these have been discarded by U.S. breeders, brachytic hybrids are being successfully grown in some South American countries.

E. UTILIZATION OF INTERNATIONAL TESTING IN BREEDING
FOR BIOTIC AND ENVIRONMENTAL STRESS RESISTANCE

Rappateur: Herman L. Warren - Purdue University

We divided this issue into two parts, international testing and breeding for stress tolerances.

International Testing. There is a need to evaluate germplasm for biotic and environmental stresses (identify resistance characteristics) prior to the breeding process. Information obtained from this research should be made available to breeders. CIMMYT may also need to screen their germplasm banks for these characters and make selections based on resistance to stress.

Breeding for Stress Tolerance. No single site or location has an environment suitable to breeding for all types of stress resistance. CIMMYT has several locations where germplasm is tested. National programs, however, may have additional or different priorities than the CIMMYT world-wide adaption program. Breeding for stress resistance should first be done in a few locations where more than one-half of the stress characters can be evaluated. These populations should then be adapted to specific environments where they will be used.

Constraints and Opportunities for Collaborative Breeding Research.

CIMMYT's mission for worldwide adaption of germplasm may not always coincide with the priorities of LDC national programs. A national program may choose to modify or change research emphases to include stresses that are not pressing in their program. More likely, equipment, laboratory space and trained personnel may not be available to monitor all of the problems associated with stress research in their program environments. An alternative proposal is that CIMMYT initiate bilateral programs with U.S. institutions to research such problems.

With our present knowledge we can identify most stress characters. A major problem exists, however, because techniques that allow scientists to combine some stress tolerance in varieties and populations are not available for all stresses. The mechanisms of resistance to environmental stresses are not known. Mechanisms of resistance to biotic stresses (diseases and insects) are better understood, but more research is needed. This is an area of research well suited for U.S. university collaboration.

There is a need for CIMMYT to accurately identify, document and characterize environmental and biotic stress resistances in their populations. These data need to be assimilated and made available. This kind of information would add to the value of each collection and allow researchers to develop known stress resistance from this germplasm. National programs may be inclined to use these populations to breed for specific tolerances in their countries.

International Testing Program.

Some Tricicum species are known to have waxy leaves. It is suggested that CIMMYT intercross waxy leaf Tricicum species with maize to develop waxy leaf maize. The waxy leaf may reduce transpiration and thus make the germplasm more drought resistant.

CIMMYT may need to evaluate selected germplasm developed by national programs because these may be a good source of specific resistance. National program breeders should also evaluate CIMMYT germplasm. This is one way to test for worldwide adaption and variability to pest resistance. Resistance to different stresses may not be independent and correlated resistance could be identified. CIMMYT is doing a good job in this area.

Reduced tillage practices are becoming established in the LDCs as well as in the United States. These practices can bring about changes in environmental and biotic stresses. Alleopathy has been observed in many reduced tillage cultures. Problems occur with fertility or fertilizer placement and pests. U.S. universities have the expertise to cooperate effectively with CIMMYT in this area.

CIMMYT - U.S. Universities Interaction and Collaboration

1. U.S. universities can test cropping practices and biotic and environmental factors associated with reduced tillage.
2. U.S. universities have the capability to develop techniques for evaluation of stresses such as basic physiological studies.
3. Recent progress in molecular biology and genetic engineering at U.S. universities could aid CIMMYT's mission for developing drought resistant germplasm. Tissue culture, for example, has aided in the development of drought resistant germplasm at Mississippi State University.
4. U.S. universities could collaborate in studies of the biochemical bases for resistance to diseases and insects, such as the identification of compounds for resistance to insects.
- 5) U.S. universities have and can train students in the agricultural sciences that are needed in the LDCs. CIMMYT might institute a small grant program to encourage U.S. universities to participate in maize training programs.
- 6) U.S. universities and CIMMYT should develop effective mechanisms for their scientists to interact on the broad range of problems dealing with maize germplasm and improvement.

Comment: James L. Brewbaker, University of Hawaii

Would you please consider listing incident light stress tolerance and day-neutrality research as a major topic for collaborative study with the University of Hawaii and other institutions. By weekly planting in a windward area under low winter light, we have produced some very good data on incident light and grain fill, and evidence for genetic control of the variability encountered. We would be interested in collaborating with CIMMYT on such further studies.

VI. ON-FARM RESEARCH PROGRAMS FOR MAIZE

ISSUES

- A. Adequacy of On-Farm Research Methodology to Provide Useful Results in LDC Breeding Programs.
- B. Role of OFR in Developing/Extending Agronomic Production Programs With Improved Varieties.
- C. Identification of Problems and Needs Through OFR and Feedback to CIMMYT and National Programs.
- D. Production Research Necessary to Backstop On-Farm Research Programs.
- E. Role and Requirements of LDC National Programs for Effective On-Farm Research and Maize Production.

A. ADEQUACY OF ON-FARM RESEARCH METHODOLOGY TO PROVIDE
USEFUL RESULTS IN LDC BREEDING PROGRAMS.

Rappateur: Thomas Stillwell - Michigan State University

There was unanimous agreement that an active on-farm research (OFR) program benefits plant breeding programs by providing information on selection criteria to be used. Several examples were cited:

- In Ecuador the OFR program identified a need for short season varieties. When an early variety was introduced, OFR was a source of information concerning characteristic problems of the variety.
- In Egypt no variety is released without on-farm testing.
- In the Dominican Republic OFR showed a definite farmer preference for thin cob varieties.
- In Colombia varieties are tested in various on-farm locations to determine the best area for release of a variety.
- In Ecuador OFR has been most useful for establishing priorities and strategies in their breeding programs. It has not been as successful, however, in defining an ideal variety for a given valley.

In the U.S. the detection of such problems and their solutions is usually done by the private sector through a highly developed seed industry. The private sector is not sufficiently developed in most developing countries to serve this role. OFR has been developed to provide national programs a mechanism to detect and solve these technological problems for the adaptation of new methodologies.

We have observed that in programs which have on-farm variety testing the results are often invalid because the trial conditions (fertilizer, herbicide, etc.) differ from farmer practices.

The following specific topics were suggested for potential collaboration among U.S. universities and CIMMYT:

1. Changes in genotype-environment interaction between the experiment station and farmer's fields.
2. Changes in genotype-environment interactions between monocropping, mixed cropping and intercropping systems.
3. Effect of organic vs mineral fertilizers on variety performance.
4. Methods and models for disease, insect and weed pest assessment under farm conditions. Disease and storage pest problems were specifically identified.
5. Development and evaluation of conservation practices in OFR programs.

In training LDC scholars it was suggested that U.S. scientists stress the need to understand farmer conditions and not follow blindly in the U.S. example when they return to their country. The objective is to show examples of different methodologies used in the U.S.

B. ROLE OF ON-FARM RESEARCH IN DEVELOPING/EXTENDING AGRONOMIC PRODUCTION PROGRAMS WITH IMPROVED VARIETIES.

Moderator: Richard A. Frederiksen - Texas A&M University
Rappateur: Chris O. Andrew - University of Florida.

We are in the business of technology generation and use. Mutual interaction between U.S. universities, CIMMYT and national institutions in less developed countries can be viewed as covering three areas of joint responsibility for a successful research and extension system. In private sector terms these are:

Process - Role of on-farm research (OFR) in developing/extending agronomic production programs, further specified as technology generation and integration in a research/extension (R/E) system;

Product - Improved agricultural production stimulated by improved technology rooted in improved varieties;

People - Educating, training and rewarding a critical mass of agronomists to interface with basic researchers, the interdisciplinary team (linking the biological and socio-economic scientists) and the farmer.

Process: Role of OFR and Methodology

The role of OFR with a farming systems perspective is to give integrity to the research and extension process by (a) closing the gap between research and extension, (b) providing an approach to technology generation and utilization, and (c) through farmer involvement with the research/extension program.

OFR also brings the farming system into research by recognizing (a) the unique management problems of the farmer/client, (b) the role of interdisciplinary problem solving to assist the farmer, and (c) the necessary linkage to basic research.

OFR is where the "rubber hits the road" and may be the most important activity in CIMMYT according to our group. Our varieties must be able to perform on the farm. OFR provides an opportunity to bridge the gap from research to use, to realize the net product of all of our investments, to initiate the technology transfer process, and to validate the research/extension system.

Group comments relative to OFR in the research and extension process are summarized as follows:

1. Research and Extension

- (a) There is a need to develop a complete methodology for OFR with a farming systems perspective that will work through and with national programs.
- (b) Emphasis must be on the research and extension linkage.
- (c) There is need for a refined methodology for developing recommendations.

2. Research

- (a) CIMMYT is complimented for minimum tillage applications to small farms, the simple approach to OFR experimentation, and other approaches such as replications among farms to maintain simplicity.
- (b) Emphasis should be continued on good station research as a basis for good OFR.
- (c) Our universities and CIMMYT should specifically address better statistical training to facilitate use of OFR methods, and better economic analysis and feedback.

3. Extension

- (a) Systems of extension in many countries are not sufficiently developed to carry the load. In Africa the French oriented systems are stronger than the British oriented systems.
- (b) In many instances numbers prevail, but ability is reduced by lack of training and job responsibilities that are too diverse.
- (c) Extension involvement is essential or a change will not occur.
- (d) Our universities, CIMMYT and national institutions should focus on training extension agents particularly in OFR methodology.

Product: OFR Fine Tunes Station Research

Since this workshop has focused on improving varieties, there was little said about this point in our discussion. Throughout the workshop, however, our group and CIMMYT are commended for considering criteria and concerns of the farmer/client. For adoption an improved variety must meet the production capability of the farmer and ultimately the market reflected desires of the consumer. This becomes a process of converting science to a technology useful to farmers in unique social and agroclimatic environments.

The group recognized that input systems and various agricultural policies must be conducive to improved production and, where they are not, every effort should be made to adjust the technology to fit into the system.

People: OFR and Human Resource Development

Our group recognizes that the greatest challenge we face may be preparing the general agronomist for a role in the OFR activity. The generalist in agronomy, economics, and related areas, is essential for sound interdisciplinary problem solving in OFR. Preparation for this work must be made within formal and non-formal, short and long term training programs.

Various approaches to broad based and more appropriate training for both basic and OFR research in less developed countries include:

1. Better training specifications for people going to U.S. universities so the need is properly communicated to graduate committees;
2. More in-service training opportunities such as CIMMYT's "Call" program;
3. Expanded workshops to include various research and extension peer groups on both country and regional bases; and

4. Better preparation of U.S. technical assistance teams for international advisory assignments in general and for OFR in particular.

Recommendations: University/CIMMYT Collaboration

Our general recommendations center on better programming with national institutions, and particularly where U.S. universities might strengthen technical assistance through improved linkages with CIMMYT. We recommend:

1. University teams receive more intensive advance training by drawing upon CIMMYT experience;
2. Regional linkages be developed between CIMMYT and University/Country contractors to assist in establishing sound programs where early experience by CIMMYT will enhance program implementation;
3. Emphasis be given by CIMMYT and universities to building strong research/extension linkages; and
4. CIMMYT and universities commit to building regional networks which will facilitate transfer of university experience from country to country and thereby foster networks of LDC scientists.

Our specific recommendations given here can be briefly summarized in three points as:

1. Develop OFR statistical training;
2. Augment extension training through in-service OFR training programs; and
3. Continue strong experiment station research development to support OFR.

C. INDENTIFICATION OF PROBLEMS AND NEEDS THROUGH OFR AND
FEEDBACK TO CIMMYT AND NATIONAL PROGRAMS.

Moderator: Joseph Fajemisin - IITA

Rappateur: John H. Sanders - Purdue University

Our group considered the following three items in response to this issue:

1. Role of collaborative research in OFR
2. OFR feedback to CIMMYT
3. Feedback to national programs

Role of Collaborative Research

The debate on OFR data for feedback purposes raised two major questions.

- 1) What becomes of the enormous amounts of data from OFR? Is it published? Do other researchers have access to it?
- 2) An opposing view expressed against publication is that CIMMYT is analogous to a seed company in that it produces material, but does not publish and should not be expected to publish scientific results.

Feedback to CIMMYT

Examples of successful OFR feedback to the CIMMYT Program from international variety trials include: (a) need for a good husk cover; (b) importance of downy mildew; (c) importance of stalk and ear rots. Some asked if OFR was necessary to provide this feedback because such information should be available from the variety testing program. Others questioned how much OFR was necessary, and if it would be possible to move more quickly to promoting extension and changing public policy. Obviously not all in our group are convinced of the value of OFR.

Feedback to National Programs

Dr. Li reported that in China they do not do systematic OFR, but they do get information back from the farm level and utilize it in the breeding program. Feedback to research cited in other national programs includes (a) the Guatemalan experience and (b) many cases of CIMMYT varieties being chosen by national programs which is really "feed-forward".

We believe the majority opinion is that OFR is useful for feedback to CIMMYT and to the national programs on research problems and needs. There is some concern about how OFR data is generated and how it can be made more uniform and comparable between regions. Some suggested that processing of this data should be done either by CIMMYT or in collaboration with U.S. institutions. Others suggested that the real problems and need for collaboration are in the transfer of technology and appropriate agricultural policies, based on their belief that the technology is there and it is only necessary to move it forward. There is the implication in this that the universities should be involved in helping to identify socio-economic factors impeding the technology transfer.

Observations By the Rappateur

Is it not time for the CIMMYT agronomists and economists, after many years of methodology development, to systematically produce data and analysis from OFR and to test their methodologies for their contribution to technology evaluation within CIMMYT and national programs? If their analyses should challenge some of the assumptions or strategies of other scientists they may not be very popular, but is not this type of feedback necessary to both national and international programs? In addition to refereed journals, CIMMYT has its own bulletins as a publication outlet.

Many are still convinced that the barriers to more rapid diffusion are somewhere outside of the technology production process. At CIAT in Colombia it was also believed that the technology was ready and the barriers were extension, agricultural policy and socio-economic factors. After doing four years of farm testing and analysis I can report that much of the technology that was successful on the experiment station and the regional site, either did not function the same or was not profitable on farmers' fields. The assumption that the barrier to development is the transfer of technology, and not its development and refinement for farmers' conditions, does not seem valid, especially in the absence of OFR data and analysis.

D. PRODUCTION RESEARCH NECESSARY TO BACKSTOP ON-FARM RESEARCH PROGRAMS.

Rappateur: Eugene J. Kamprath - North Carolina State University.

We defined production research as including both basic and applied research which provides information needed to increase crop yields. On-farm research programs would not undertake studies which involve basic mechanisms, require sophisticated equipment or would be expensive to conduct. These are studies in which U.S. universities could collaborate with CIMMYT.

Agromomic studies with maize are done by CIMMYT on a country and regional basis. In the evaluation of CIMMYT varieties it is essential that the soils at each experiment station and on-farm research site are classified according to soil taxonomy. The chemical properties of the soil should also be characterized. This is necessary if results of the on-farm research and the international testing program are to be extrapolated to other areas in the tropics. Assistance in soil classification can be obtained from the Soil Management Support Systems of the USDA Soil Conservation Service.

The Soil Management CRSP is developing basic information in tropical regions on soil chemical properties, soil factors limiting crop production, critical soil test levels and methods of soil testing. This program involves four U.S. universities and national programs in a number of countries in Latin America, Africa and Asia. Networking between the Soil Management CRSP and CIMMYT will provide information of mutual benefit to both groups.

U.S. universities can collaborate with CIMMYT in other areas such as basic studies on reactions of herbicides in tropical soils and the effects of various management practices on these reactions. Faculty of U.S. universities can help in identification of disease and insect problems which cannot be handled by national programs. Basic studies on control of diseases and insects can be done in U.S. institutions.

On-farm research programs can help identify the factors in crop production and soil management which require basic, in-depth studies. It is important that CIMMYT and U.S. universities establish the linkages to do these studies.

U.S. universities can make an important contribution in the training of graduate students of developing countries in the area of soil management and crop production. Where possible, graduate students should do their dissertation research in their own country. There should be close interaction between the CIMMYT staff in the country or region and the graduate student. Where it is not possible for the student to do his thesis research in his own country, a research problem should be developed which will relate to either present or future needs in his country. Graduate students should be made aware of the Farming Systems Support Project in association with a number of U.S. universities. Whenever possible, students should participate in short courses or workshops conducted by the Farming Systems Support Project.

After graduate students return to their home countries it is important that they maintain contact with faculty of the university which granted their degree. It is also important that the student establishes contact with the staff of the International Research Centers doing work in their country or region. Returning graduate students should become involved with CIMMYT workshops and training sessions in their country or region.

It is important for the professional development of new research workers to have an association with other researchers. A mechanism needs to be developed whereby they can establish and maintain such professional contacts.

The identification and feedback of factors needing to be researched and the dissemination of research findings to farmers requires a well trained extension staff. The type of training needed and the method of doing this requires the efforts of both U.S. universities and CIMMYT.

E. ROLE AND REQUIREMENTS OF LDC NATIONAL PROGRAMS
FOR EFFECTIVE ON-FARM RESEARCH AND MAIZE PRODUCTION

Rappateur: John Stovall - BIFAD

We first considered the general issue of whether we had any advice or suggestions to offer the CIMMYT Maize Program and concluded we had none. We concluded that the most significant assistance U.S. universities could offer the CIMMYT OFR program was through training of LDC students who will be future members of Country Research and Extension programs. This already is being done, but its importance should be emphasized.

We recognized that U.S. universities are already making a contribution to the further development of OFR methodology at CIMMYT through collaboration with the AID financed Farming System Support Project under the leadership of the University of Florida and a network of scientists in a number of U.S. universities, and that there is a modest potential for increasing this input. We identified dissertation research by LDC students at U.S. universities as having untapped potential for complementing relevant problem solving research and feedback which would enhance the linkage between Research and Extension in LDCs, and also with on-farm research at CIMMYT.

Bilateral programs carried out by U.S. universities offer an opportunity to enhance and speed up technology transfer and adoption through

- Special socio-economic studies which will help CIMMYT to better address LDC conditions and constraints
- Assistance to improve extension techniques
- Modification of policies constraining technology adoption
- Assisting LDC officials to understand the implications of policies which are adverse to adoption of technology improvement for increased food production.

Other considerations include appropriate technology, education of U.S. students, and appropriate curriculum planning.

