Introduction

Objectives of Study

During the early 1990s, researchers at the International Maize and Wheat Improvement Center (CIMMYT) carried out a major study to document the global impacts of international maize breeding research. The results, published in 1994 in a CIMMYT monograph entitled *Impacts of International Maize Breeding Research in the Developing World, 1966-1990*, provided a wealth of information about germplasm products of maize breeding programs in developing countries and sketched out a compelling picture of the widespread dissemination of improved maize varieties and hybrids (López-Pereira and Morris 1994). In subsequent years, the data generated by CIMMYT's global maize impacts study came to be recognized as definitive and were widely used for a broad range of research investment and research management activities.

Following the completion of the initial study, CIMMYT made a commitment to update and extend its global maize impacts database and to publish summary reports approximately every five years. Regular updating of the database was considered important given the rapid rate of technological change that characterizes the global maize economy. Extending the database was considered necessary given the lack of success achieved during the initial study to collect detailed and comprehensive information from the private sector. Publishing summary reports was considered essential for making the latest information available to a wide range of research managers, policy analysts, and government decision-makers.

Efforts to update and extend CIMMYT's global maize impacts database were initiated in 1997. Given the enormity of the data collection task, the global impacts study was divided into three regional impacts studies—one each for Latin America, Eastern and Southern Africa, and Asia (see Morris and López-Pereira 1999; Hassan, Mekuria, and Mwangi 2001; Gerpacio 2001). This report summarizes and extends the results of the three regional studies and discusses the implications for future maize breeding research.

Many objectives of the current study resemble those set out in the original global maize impacts study:

- estimate the level of public- and private-sector investment in maize breeding research in developing countries,
- document germplasm outputs of public and private maize breeding programs in developing countries,
- document the use of CIMMYT materials by public and private maize breeding programs in developing countries,
- estimate the rate of farm-level adoption of improved maize germplasm in developing countries, and
- estimate the use of modern maize varieties developed using CIMMYT germplasm.

Two additional objectives of the current study are to estimate the value of additional grain production attributable to (1) international maize breeding research in general, and (2) CIMMYT's maize breeding program in particular.

Sources of Information

In addition to drawing on the original impacts data collected in 1992, this report presents new data collected during 1997, 1998, and 1999 through an extensive survey of public and private maize breeding organizations and seed companies located in 37 developing countries in Latin America; Eastern and Southern Africa; and East, South, and Southeast Asia (see Table 1 for list of countries).

Table 1. Coverage of CIMMYT global maize impacts study.

Latin America	Africa	Asia
Caribbean	*Eastern Africa*	*East Asia*
Cuba[a]	Ethiopia[a]	Southern China[a]
Dominican Republic[a]	Kenya[a]	Northern China[d]
Haiti[a]	Tanzania[a]	
	Uganda[a]	*South Asia*
Mexico and		India[a]
Central America		Nepal[a]
Costa Rica[a]	*Southern Africa*	Pakistan[d]
El Salvador[a]	Angola[a]	
Guatemala[a]	Lesotho[a]	*Southeast Asia*
Honduras[a]	Malawi[a]	Indonesia[a]
Mexico[a]	Mozambique[a]	Philippines[a]
Nicaragua[a]	South Africa[a]	Thailand[a]
Panama[a]	Swaziland[a]	Vietnam[a]
	Zambia[a]	
Andean Zone	Zimbabwe[a]	
Bolivia[a]		
Columbia[a]	*West and Central Africa*	
Ecuador[a]	Benin[b]	
Peru[a]	Burkina Faso[b]	
Venezuela[a]	Cameroon[b]	
	Chad[b]	
Southern Cone	Congo, D.R.[b]	
Argentina[a]	Côte d'Ivoire[c]	
Brazil[a]	Ghana[b]	
Paraguay[a]	Guinea[b]	
	Mali[b]	
	Nigeria[b]	
	Senegal[b]	
	Togo[b]	
	North Africa	
	Egypt[c]	

[a] CIMMYT survey [b] IITA survey
[c] Subjectively estimated [d] National maize program
Source: CIMMYT maize research impacts survey.

Compared to the first survey conducted in 1992, the follow-up survey went to greater lengths to collect data from the private sector. Detailed questionnaires were completed by the directors of 104 public maize breeding institutes and seed production agencies, as well as by representatives of 267 private seed companies. Virtually all of these respondents were personally interviewed; only in rare cases was information collected by mail, through a telephone interview, or from secondary sources.

Many survey respondents—not only from the private sector but also from the public sector—indicated that some of the information solicited for this study is considered sensitive due to its potential value to competitors (for example, pedigrees of commercial hybrids, research investment data, cultivar-specific seed sales data). For this reason, CIMMYT pledged to treat as confidential all primary data.

To extend the coverage of the study, secondary data were obtained for a number of additional countries and regions that were not directly surveyed:

- ***West and Central Africa:*** Among the international agricultural research centers supported by the Consultative Group for International Agricultural Research (CGIAR), the mandate for maize improvement in West and Central Africa is held by the International Institute for Tropical Agriculture (IITA). IITA recently conducted an impacts study within its mandate area (Manyong et al. 2000). To provide a more complete global picture of MV adoption and impacts, selected findings of the IITA impacts study relating to West and Central Africa were included in the present analysis. Since Côte d'Ivoire was not included in the IITA survey, MV adoption data for Côte d'Ivoire were subjectively estimated by adjusting the results of the 1992 CIMMYT survey to account for recent developments in the national maize sector.
- ***Northern China:*** For logistical reasons, northern China was not included in the CIMMYT survey. Shortly before this publication went to press, sources in China's national maize breeding program reported that approximately 10% of the

area planted to maize in northern China (roughly 2 million ha) is planted to cultivars with some degree of CIMMYT parentage (S. Zhang, personal communication). Because northern China was not included in the CIMMYT survey, this estimate could not be supported by seed sales data or variety-specific adoption data. Nonetheless, the area was included in the varietal adoption estimates and economic benefits calculations.

- ***West Asia and North Africa (WANA region):*** For logistical reasons, countries in the WANA region were not included in the survey. The WANA region includes five countries in which 100,000 ha or more are planted to maize: Afghanistan, Egypt, Iran, Iraq, Morocco, and Turkey. For Egypt, the area planted to maize MVs was subjectively estimated by adjusting the results of the 1992 CIMMYT survey to account for recent developments in the national maize seed sector. The other five countries account for less than 3% of the developing world's maize area, so their omission is not likely to have a significant influence on global summary statistics.
- ***Pakistan:*** Mainly for logistical reasons, Pakistan was not included in the survey. The area planted to maize MVs in Pakistan was subjectively estimated by adjusting the results of the 1992 CIMMYT survey to account for recent developments in the national maize sector, taking into consideration information provided by sources in Pakistan's national maize research program (M. Aslam, personal communication).

Geographical Coverage

The geographical coverage of the analysis presented in this report varies depending on whether it is based on the primary survey data alone or on the primary survey data plus the secondary data. The descriptions of research investment trends (Section 3) and cultivar release patterns (Section 4) are based on primary survey data and therefore relate to 37 countries representing 75% of the developing world's maize area. The analysis of varietal adoption patterns (Section 5) and the economic benefits calculations (Section 6) are based on primary survey data plus secondary data and therefore relate to 51 countries representing over 97% of the developing world's maize area.

WHY MAIZE IS DIFFERENT FROM OTHER CROPS

Distinctive Characteristics of Maize

Maize differs from other crops in a number of respects that affect not only the way international breeding efforts are organized and carried out, but also the process by which improved varieties[1] are taken up by farmers and diffused across the countryside. Before attempting to interpret the impacts data presented later in this report, it is important to understand these distinctive characteristics that make maize different.

OPEN POLLINATION

Maize (*Zea mays L.*) is a monoecious species, with a male flower (tassel) located at the top of the stem and female flowers (ears) located about mid-way down on the same plant. This spatial arrangement of the flowers facilitates both selfing (pollination of the female flower with pollen from the same plant) and crossing (pollination of the female flower with pollen from a different plant). Reproduction in maize is initiated when pollen shed from a tassel fertilizes ovules located in the ear. Each tassel on a mature maize plant can produce up to 10 million male gametes (pollen grains). These pollen grains are enclosed in anthers, which open a few days before the silks (stigmas) emerge on the ears. Within minutes of

[1] Throughout this report, the term *varieties* is used in a generic sense to refer to both open-pollinating varieties as well as hybrids. The term *OPVs* more specifically refers to open-pollinated varieties that have been improved by a formal breeding program.