



The CGIAR at 31: An Independent Meta-Evaluation of the Consultative Group on International Agricultural Research

**Thematic Working Paper
International Agriculture Research and the Role of the
Private Sector**

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Abbreviations and Acronyms

CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical (CGIAR)
CIFOR	Center for International Forestry Research (CGIAR)
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (CGIAR)
CIP	Centro Internacional de la Papa (CGIAR)
DGF	Development Grant Facility (World Bank)
ICAR	Indian Council on Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas (CGIAR)
ICLARM	International Center for Living Aquatic Resources Management (CGIAR)
ICRAF	International Center for Research in Agroforestry (CGIAR)
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics (CGIAR)
IFPRI	International Food Policy Research Institute (CGIAR)
IITA	International Institute of Tropical Agriculture (CGIAR)
ILCA	International Livestock Center for Africa (CGIAR)
ILRAD	International Laboratory for Research on Animal Diseases (CGIAR)
ILRI	International Livestock Research Institute (CGIAR)
IPR	Intellectual property right
IRRI	International Rice Research Institute (CGIAR)
NARS	National agricultural research systems
OECD	Organization for Economic Cooperation and Development
OED	Operations Evaluation Department (World Bank)
R&D	Research and development
TSR	Third System Review (CGIAR)

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Preface

This is one of five thematic working papers by independent scholars prepared as part of the meta-evaluation of the Consultative Group on International Agricultural Research (CGIAR) conducted by the Operations Evaluation Department (OED) of the World Bank. The report, entitled *The CGIAR at 31: An Independent Meta-Evaluation of the Consultative Group on International Agricultural Research*, is available on OED's external Web site: <http://www.worldbank.org/oed/gppp/>. The thematic working papers are: C. B. Barrett, "Natural Resources Management Research in the CGIAR: A Meta-Evaluation," C. K. Eicher and M. Rukuni, "The CGIAR in Africa: Past, Present, and Future," B. Gardner, "Global Public Goods from the CGIAR: An Impact Assessment," W. Lesser, "Reviews of Biotechnology, Genetic Resource and Intellectual Property Rights Programs," and D. J. Spielman, "International Agricultural Research and the Role of the Private Sector."

The report on the CGIAR is part of a two-phase independent review by OED of the World Bank's involvement in global programs. The first phase has been published: *The World Bank's Approach to Global Programs: An Independent Evaluation, Phase 1 Report* (OED, Washington, D.C., 2002). The second phase, due in fiscal 2004, involves case studies of 26 programs, of which the CGIAR is one. The inclusion of the CGIAR evaluation in the OED review of the Bank's global programs was requested by the Development Grant Facility (DGF) and Bank Management in June 2001, and endorsed by OED's global program advisory committee.

While the focus of the meta-evaluation is on the Bank and the strategic role it has played and ideally will continue to play in the future in ensuring the CGIAR's development effectiveness, the thematic and country working papers and the country background papers focus on the different components of CGIAR activities that determine impact, including country perspectives. In addition to informing a broader understanding of the policy and technical context of CGIAR implementation, the papers provide a tool for assessing the performance and impact of the whole CGIAR partnership; this, in turn, provides a critical context for gauging the impact and value added of the Bank's participation in the program, the primary objective of the CGIAR meta-evaluation.

All five thematic working papers are based on extensive reviews of CGIAR's own evaluations as well as other related scholarly literature and discussions with relevant stakeholders. Four of the five thematic working papers were extensively peer-reviewed by knowledgeable external experts. A list of working and background papers and peer reviewers for the working papers is provided in Annex 2.

In addition, four country case studies on Brazil, India, Colombia, and Kenya provide developing country perspectives on the CGIAR. Two of the four – a study on India, written by Dr. J. C. Katyay and Dr. Mruthyunjaya, and a study on Brazil, by Jamil Macedo, Marcio C.M. Porto, Elisio Contini, and Antonio F.D. Avila – are issued as country working papers. The other two – C. Ndiritu, "CGIAR-NARS Partnership: The Case of Kenya" and L. Romano, "Colombia Country Paper for the CGIAR Meta-Evaluation" – are available on request.

The CGIAR was the first program providing global public goods to receive grants from the Bank's net income. Although the program has an impressive tradition of self-assessments, System-level evaluations have been few and far between. An exception, the Third System Review (TSR), was carried out in 1998, 17 years after the previous System-level review. OED determined that a meta-evaluation would most effectively assess CGIAR performance and inform OED's overall review of the Bank's involvement in global programs. In brief, the objectives of the meta-evaluation were three-fold:

- Evaluate implementation of recommendations in the 1998 TSR review
- Identify issues confronting the CGIAR from a forward-looking perspective
- Draw lessons for overall Bank strategy on global public policies and programs

The meta-evaluation report is in three volumes. *The Overview Report (Volume 1)* addresses strategic questions regarding the organization, financing, and management of the CGIAR as these have affected research choices, science quality, and the Bank's relationship to the CGIAR. *The Technical Report (Volume 2)* explores the nature, scope, and quality of the System's scientific work, assesses the scope and results of the reviews, and analyzes the governance, finance, and management in the CGIAR. *The Annexes (Volume 3)* provide supporting materials and are available on request.

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1. Introduction

1.1 The role of the private sector in agricultural research and development (R&D) has increased significantly in developing countries over the past two decades. However, information on the nature of private sector R&D in agriculture its focus, location, size and output is limited in availability, thus limiting any analysis of the potential risks and opportunities of this growth trend. The objective of this paper is to review the available information on private sector investment in agricultural R&D in the developing world as a means of contributing to an evaluation of the Consultative Group on International Agricultural Research (CGIAR). This paper intends to argue the following:

- Private sector investment in agricultural R&D is, by all accounts, growing rapidly in the developing world, while the growth rate of funding for agricultural R&D by public and international institutions is concurrently decreasing.
- Private sector agricultural R&D investments in the developing world are specific to a limited number of crops, markets, countries and technologies, and do not represent a comprehensive mechanism for technological transfer and progress that will sufficiently contribute to increasing rural incomes and alleviating poverty in many developing countries.
- The current focus on improving private sector incentives such as intellectual property rights (IPRs) is closely related to the larger issue of market openness, information asymmetries, and efficiency in the agricultural seed and input markets throughout the developing world.
- There exists no single pattern of private sector investment in agricultural R&D in developing countries, thus allowing for different and innovative approaches to public-private partnerships that may potentially increase research productivity and spillover benefits.

1.2 Based on these arguments, this paper suggests that further research should be undertaken to (a) identify technologies of specific importance to agriculture in developing countries that can be developed in cooperation with the private sector; (b) analyze the effects of increasing industry concentration among multinational research firms on output, prices and economic welfare; (c) evaluate the progress of reforms and liberalization in seed and input markets in the developing world; (d) measure the potential contribution of new and innovative partnerships between the public and private sectors; and (e) understand the CGIAR's role in fostering such partnerships to facilitate agricultural R&D. These suggestions are aimed at promoting agricultural R&D as a means of increasing rural sector incomes and alleviating poverty in developing economies.

1.3 This review incorporates information from a wide variety of sources, including policy documents from international organizations and governments, literature from private firms and their interest groups, published articles from the academia, and policy forum presentations. However, there are significant limits on the availability of information on the private sector's growing role in agricultural R&D. Firms are often unable or unwilling to provide data that they consider strategic or proprietary. Industry-level data are constrained by lacking specificity in definitions currently used to categorize industry sectors and subsectors. The indivisible and diffuse nature of technology and the

firms and institutions that undertake R&D also makes it difficult to determine the size of investments in a single technology in a particular country at a specific point in time.

1.4 Despite these constraints, however, we begin our review in Section 2 with a brief discussion of the critical institutional and market forces contributing to the growth of the private sector's role in agricultural R&D. Section 3 presents a typology of private sector investment in agricultural R&D in developing countries. Section 4 discusses the emerging forms of public-private partnerships in agricultural R&D. Section 5 sets forth the issues central to continued private sector growth and investment in agricultural R&D in the developing world, followed by concluding remarks in Section 6.

2. Determinants of Private Sector Growth

2.1 The growth of private sector investment in agricultural R&D in developing countries is related to changing demand factors, increasing openness in and liberalization of agricultural markets, improvements in the incentives facing private agents, and new technological breakthroughs. We broadly examine each of these points in turn before addressing them in detail in subsequent sections of this paper.

2.2 The growth of private sector R&D in the developing world is easily attributable, in part, to increasing demand for agricultural production. This trend is most significant in the high-growth economies of East and Southeast Asia, for instance. Here, demand for agricultural output has expanded while the typical sources of agricultural growth have concurrently declined or stagnated (Pray & Fuglie, 2001). Rising incomes and rising demand for higher value agricultural goods such as meats, fruits and vegetables have been accompanied by declining or slowing rates of land and irrigation expansion, agricultural labor growth, and public sector R&D. These growing demand conditions have generated a derivative demand for more modern inputs, resulting in upward revisions of future returns to R&D by the private sector. A telling measure of this trend is the fact that private sector R&D expenditure has, according to Pray & Fuglie (2001) increased at the same rate as agricultural GDP growth in Asia. Of course, in other regions of the developing world, the increasing demand for agricultural output is more related to population pressures than increasing incomes.

2.3 But in many countries, demand factors are only part of the story. Increasing marketization of agricultural input sectors may represent an important contribution to private sector growth in agricultural R&D. Openness to trade and investment in products embodying new technologies has increased in many developing countries, resulting in increasing imports of improved seeds and other agricultural inputs, along with foreign direct investment in input sectors. Liberalization of domestic markets for agricultural inputs is also making it possible for private sector agents to enter and compete successfully. Institutional changes designed to improve incentives to the private sector, such as stronger IPR regimes, are also underway. Though these changes are at a nascent stage in many developing countries, there is evidence of an increasing trend towards marketization, thereby increasing the incentives to private sector investment in agricultural R&D.

2.4 With improvements in market efficiency, private firms are able to realize potentially attractive rates of returns to their investments in agricultural R&D. Rates of return to agricultural R&D, whether conducted by the private or public sector, are, according to many studies, highly positive. However, there is insufficient information on private sector returns, especially when it comes to developing country R&D. A meta-analysis of studies estimating rates of return to agricultural R&D conducted by Alston et al. (2000) aptly illustrates this point: of the 392 studies on rates of returns included in the meta-analysis, only 25 were studies conducted on private sector research, and fewer still on developing countries. Studies conducted on private sector R&D in developing countries generally suggest positive private and social returns. Such studies include investigations of different crops in India (Ribeiro, 1998); the impacts of private sector R&D on factor productivity in India (Everison et al., 1999); and maize yields in temperate and tropical regions (Echeverria, 1991), to name a few.

2.5 Breakthroughs in genetic engineering and plant breeding in the mid-1980s have fostered a new round of technological innovation in agriculture and increased the potential returns to private investment in agricultural R&D. Agricultural biotechnology (agbiotech) has improved the science of plant breeding by allowing for more precise and efficient selection of desirable plant traits such as disease resistance, herbicide tolerance and valuable agronomic properties. This new technology reduces the time required to develop marketable products and to realize returns on investment. While research conducted by public institutions contributes to building the basic foundations of agbiotech, the private sector has taken the lead in developing agbiotech products for market.

3. Typology of the Private Sector

3.1 Here, we present a basic typology of private sector investment in agricultural R&D, as well as a discussion of the constraints facing private sector growth. We examine the specific nature of private sector investment as well as the characteristics of firms conducting R&D and the market and institutional environment in which they operate.

3.2 *Sectors, crops and countries.* There is significant information suggesting that private sector investment in agricultural R&D is increasing in a number of sectors, crops, and countries throughout the developing world. However, private sector investment is concentrated, at least for the time being, in specific types of countries large agricultural producers with long-standing public expenditures on agricultural R&D and on commercially valuable crops. Moreover, there is limited indication of the extent to which these processes are increasing the stock of knowledge capital in developing countries and whether significant spillover effects are being realized from increased private sector investment.

3.3 *Sectors.* Private sector investment in agricultural R&D is distributed among four key sectors: (a) agricultural chemicals, including chemicals for plant protection, fertilizers and biotechnological applications; (b) plant breeding and the production of seed and planting materials; (c) food storage, transport and processing; (d) animal and livestock improvement, and (e) agricultural equipment and machinery.

3.4 Estimates from 1995-1996 of private sector expenditure on agricultural R&D in developing countries place the figure (in 1993 international dollars) at approximately \$672 million. This constitutes less than 6 percent of all private sector investment in agricultural R&D worldwide. This also constitutes less than 6 percent of the total expenditure on agricultural R&D by both the public and private sectors in developing countries. Approximately one-third of all private sector investment in agricultural R&D is directed to agricultural chemicals, a distribution of resources that is common to both industrialized countries and many developing countries. Within the area of agricultural chemicals, pesticides and crop protection make up the largest portion of private sector R&D investment (Pardey & Beintema (2001); Pray & Fuglie (2001)).

3.5 *Crops and traits.* While most public sector R&D expenditure is allocated to farm-related technologies world over, private sector R&D investments tend to focus more on food processing and post-harvest R&D (Pardey & Beintema, 2001). And while public sector R&D expenditures on plant breeding often emphasize farm crops such as cereals and pulses, there is ample evidence to suggest that private sector R&D investments focus on more commercially viable crops. In India, for instance, the OECD reports new, primarily commercial varieties of vegetables, cotton and millet comprised 107 of the 122 varieties introduced by the private sector as of 1990 (OECD, 1994). In some regions, private sector R&D also tends to focus on a wider variety of traits than those emphasized by public sector. In a study of seed markets in southern and eastern Africa, Tripp & Rohrbach (2001) find evidence that research undertaken by national agricultural research systems (NARS) prioritizes traits such as yield improvements, while limiting research on other desirable traits such as processing quality, an area of research that typically attracts a large portion of private sector R&D investment.

3.6 An analysis of private sector investment in agricultural R&D would be incomplete without a discussion of modern agricultural biotechnologies. Private sector investment in agbiotech R&D focuses on a wide variety of traits, including herbicide tolerance, disease resistance, and agronomic properties. The bulk of this research, however, is physically located in industrialized countries (James & Krattiger, 1996). Traxler (2001) notes that the major biotechnological applications introduced in developing countries to date are limited to two traits pest resistance produced from the *Bacillus thuringiensis* (Bt) gene, and tolerance for the herbicide Roundup Ready and only four crops – soybean, maize, cotton, and canola – are based on technologies developed in industrialized countries.

3.7 *Countries.* When examining the diffusion of agricultural R&D to developing countries, agbiotech again provides the clearest evidence of the private sector's growing role in the developing world. Private sector investment in agbiotech R&D is concentrated in a few countries with large agricultural sectors or strong public research systems, such as India, China, Argentina, Brazil, and Mexico, but is spreading rapidly to other countries with valuable commercial agriculture sectors.

3.8 In 2001, approximately 52.6 million hectares were cultivated with transgenic crops worldwide, an increase of 19 percent over the prior year. Twenty-five percent of this cultivated area, or 13.5 million hectares, is located in developing countries, a figure that increased by 26 percent from 2000. Just three countries U.S., Canada, and Argentina were host to approximately 96 percent of transgenic crops under cultivation in 2001. China,

Australia, South Africa and Brazil each cultivated between 100 and 400 thousand hectares of transgenic crops, and an additional seven countries cultivate smaller areas of transgenic crops (James (2001b); James (2001a)). The majority of these transgenic crops are cultivated with seed produced and distributed by the private sector, except in China, where public R&D institutions and their commercial enterprises play a more significant role.

3.9 Between 1987 and 1995, only seven developing countries had conducted more than 15 field trials on transgenic crops. By 1999, the number of countries had grown to ten, and the number of tests in the largest countries had grown significantly. In developing countries, 87 percent of these field trials were conducted by the private sector, and in Mexico, Argentina and Brazil alone, more than 60 percent of all field trials were conducted by multinational firms, while an additional 20 percent were conducted by smaller, domestic firms (Traxler (2001); James (2001b)).

3.10 Approvals for commercialization of transgenic crops follow this same pattern of concentration in countries with large agricultural sectors and strong public research systems. Approvals are highest in China (35), followed by Argentina (5), Mexico (4), and Brazil, Uruguay, and Korea (1 each), as of 2000-2001 (Traxler, 2001).

3.11 These figures indicate that new agricultural technologies, particularly modern agricultural biotechnologies, are emerging in only a limited number of developing country markets. However, the growth in cultivation, field testing, and approvals indicates that these new technologies are expanding rapidly, at least in countries that are not fundamentally resistant to agbiotech. The primary issues here are as follows. First, to what extent is the diffusion of new technologies generating spillover benefits beyond the sale of improved seed and planting materials, i.e., are the new technologies resulting in increased technical capacity, adaptive innovation and other forms of spillovers in developing countries? Second, and equally important, is how the economic welfare benefits of these technologies are being distributed between agrarian producers and consumers. Both issues are receiving increased attention in the literature, although there is little empirical evidence available from which to draw conclusions.

Table 1: Field Tests of Transgenic Crops, Select Countries (Cumulative)

<i>Country</i>	<i>1995</i>	<i>1999</i>
Argentina	78	321
China	60	322
Brazil		223
Mexico	38	143
South Africa	22	96
Egypt	2	31

Source: ISAAA, 2002.

3.12 *Markets, Firms, and Industry Structure.* The value of international markets in seed, planting material and other inputs that embody agricultural technologies is increasing each year. Private sector investment in developing these technologies is increasingly dominated by a small number of large multinational enterprises (MNEs). However, the ability of MNEs to market inputs embodying their technologies is increasingly determined by smaller private sector agents in seed and input markets, rather than state-owned monopolies. The industry structure associated with this market is an increasingly complex environment comprising public agricultural research systems, multinational enterprises, private plant breeding and seed production firms, state-owned

corporations, and a variety of other agents. Industry structure varies from country to country, but certain general characteristics are common to most. We review here the rudimentary structure of the industry with particular emphasis on private sector agents.

3.13 *Multinational enterprises.* The MNE represents one of the most significant producers of agricultural R&D in the private sector. The MNE is particularly important in the agbiotech field, and is increasingly represented by multinational “life-sciences” firm with overlapping R&D investments in medicines and pharmaceuticals, chemicals, seed and crop protection, and biotechnology. Life-sciences firms conduct basic and applied research on transforming plant varieties with desirable traits through traditional plant breeding, genetic engineering or other scientific techniques (Traxler, 2001). Outputs include biological improvements embodied in germplasm, planting materials, or seed. The R&D conducted by these types of firms are typically high due to the costs associated with scientific capital, product testing and approval processes.

3.14 The industry has witnessed a rapid consolidation among life-sciences firms over the past decade, reflected in an ongoing process of mergers, acquisitions, joint ventures and other undertakings. Increasing industry concentration is common in sectors characterized by high fixed costs and intensive use of intellectual property and knowledge capital. Thus, the consolidation process has been strongly motivated by product complementarities, economies of scale and scope, acquisition of intellectual property rights and regulatory cost issues (Kalaitzandonakes & Bjornson (1997), Fernandez-Cornejo & McBride (2000)).

3.15 Fulton & Giannakas (2001) suggest that strategic pricing behavior and price discrimination exists in the industry, although evidence indicates that the impact is limited to the distribution of economic surplus and not the total surplus size. Some industry leaders predict that this process of consolidation will continue through 2005, at which time only five or six major life-sciences firms will be in operation, resulting in oligopolistic competition in many markets for products embodying agbiotech (CGIAR, 1999).

3.16 A breakdown of international seed sales by company is provided in Table 2 and suggests a relatively high level of industry concentration. In the field of agbiotech, the industry is even more concentrated: world sales of plant biotechnology are dominated by Pharmacia (Monsanto), accounting for 88 percent of the world market, Adventis Group (Hoechst/ Phone-Poulenc) with 8 percent, and Syngenta (Novartis) with the remaining 4 percent (Fulton & Giannakas, 2001).

3.17 In seven Asian countries (China, India, Indonesia, Malaysia, Pakistan, Philippines, and Thailand) surveyed by Pray & Fuglie (2001) the percentage of total private sector investment on agricultural R&D attributable to foreign firms in the mid-1990s accounted for anywhere between 10 percent in the case of Malaysia, to almost 100 percent in China.¹ Nine investments in R&D are largest in the agrochemicals sector, and specifically in the area of pesticides and plant protection. This is followed by R&D

1. Pray and Fuglie identify a limited number of foreign firms that might not be typically categorized as MNEs, including relatively small regional firms with R&D investments and operations in more than one country within the region.

investments in the food processing and plantation sector, which is limited to countries where foreign firms are able to own or operate plantations, such as the Philippines. The remainder of foreign R&D investment is allocated to plant breeding, seed production and livestock research. In the countries studied by Pray and Fuglie, 40 percent of all seed and livestock R&D expenditure was undertaken by foreign firms.

3.18 Nine research budgets are comparable to, and often larger than, corresponding public sector allocations. Recent figures from Traxler (2001) on agricultural research budgets at the leading life-sciences firms show a range of R&D investments, ranging from \$185 million at AHP to \$408 million at Adventis. Compare this to the CGIAR's allocation of \$229 million for plant research, or EMBRAPA's allocation for agricultural R&D of \$538 million. In the area of

biotechnology R&D alone, Monsanto Seed spent \$177 million, while the combined allocations of national agricultural research systems worldwide total just \$125 million, and while the CGIAR allocates only \$25 million and CIMMYT just \$3 million. It is worth noting, however, that agricultural R&D does not constitute the largest research area for most life-science companies. Sustainable expenditure on R&D for life-sciences firms is estimated at approximately 10 percent of total earnings (CGIAR, 1999).

3.19 *Secondary firms.* Although the importance of MNEs as a producer of agricultural R&D cannot be understated, insufficient attention is often given to the role of smaller, "secondary-level" firms. Secondary-level firms include companies that adapt traits developed by life-sciences firms or public institutions into marketable varieties or quantities. Secondary firms may conduct small levels of applied R&D that are typically less costly than the R&D undertaken by MNEs or public research institutions. They may also produce their own stocks of breeder or foundation seed, or do so for primary firms. With lower fixed R&D costs, many plant breeding firms are often small in size, and may operate independently of larger firms or as subsidiaries. Secondary firms primarily focus on the production, multiplication, conditioning, packaging, and distribution of certified seed and planting material. Multiplication and production is often conducted through contract growers, while conditioning and packaging is undertaken by the secondary firm itself. Distribution and sales are conducted through networks of wholesalers, dealers, and retailers (Morris (1998), Tripp & Pal (2001)). More on these types of firms is discussed below in the context of seed and input markets.

3.20 *Markets.* The international trade in seed is growing rapidly: over a ten year period beginning in 1985, the value of seed and planting material exchanged between countries has more than doubled from \$1.4 billion. Exports of maize, horticultural and herbage

Table 2: World Sales of Top 10 Seed Companies (1999, \$U.S. million)

<i>Company (Country)</i>	<i>Seed Sales</i>
Dupont (Pioneer) (USA)	1,850
Pharmacia (Monsanto) (USA)	1,700
Syngenta (Novartis) (Switzerland)	947
Groupe Limagrain (France)	700
Grupo Pulsar (Semini) (France)	531
Advanta (AstraZeneca & Cosun) (UK, Netherlands)	416
Sakata (Japan)	396
KWS AG (Germany)	355
Dow (USA)	350
Delta & Pine Land (USA)	301

Source: Fulton & Giannakas (2001).

crops constitute the largest portion of the seed export market. The international market for seed and planting materials, though significantly smaller than the markets for fertilizer and pesticides, is valued at approximately \$30 billion. (FIS/ASSINSEL, 2002).

3.21 The role of seed supply markets in distributing technology to agrarian producers is central to the issue of private sector investment in agricultural R&D: without efficient markets through which to sell the seed and information that embody R&D, the fundamental incentives to private sector investment may be severely limited. A strategy for improving regulatory systems and liberalizing seed markets potentially reduces the costs of technology transfers and market entry to the private firm and increases the supply of technology and information to the agrarian producer (Gisselquist & Van Der Meer, 2001).

3.22 The constraints imposed on private sector development in agricultural R&D differ from country to country. In India, for instance, government regulations barred both large Indian firms and firms with majority foreign equity from plant breeding and seed production until the late 1980s. Import regulations on germplasm further prevented private sector interests from importing germplasm for plant breeding purposes (OECD, 1994). Since this period, however, economic liberalization has allowed for private sector activity in plant breeding and seed production, including joint ventures and technical collaboration with foreign firms, and imports of new technologies and germplasm.

Table 3: Seed Market Value, Select Countries (\$U.S. million)

<i>Country</i>	<i>Market Value</i>	<i>Country</i>	<i>Market Value</i>
China	3,000	Brazil	1,200
Argentina	930	India	600
Mexico	350	Turkey	170
Morocco	160	South Africa	150
Egypt	140	Chile	120
Nigeria	120	Kenya	100

Source: FIS/ASSINSEL, 2002.

3.23 Tripp (2001) identifies information asymmetry problems in seed markets as a key challenge to the diffusion of new and beneficial technologies to agrarian producers. Tripp argues that information asymmetries and market inefficiencies can persist even with the growth of market size, liberalization of overly regulated markets, and improvements in the incentives facing private seed firms. Specifically, he points out that since genetic qualities of seeds are indiscernible except through utilization experience or reputation, firms and governments must improve their ability to transmit information on inputs appropriate to their consumers' specific needs. In many developing countries, the institutions and market incentives designed to reduce these information asymmetries are weak: poor certification systems, problematic incentives to input merchants, limited extension services, and weak consumer protections all serve to sustain information asymmetries and seed market inefficiencies.

3.24 There are numerous studies citing the need for improved seed market efficiency to support the diffusion of improved seed varieties and to stimulate private sector investments in agricultural R&D. World Bank evaluations of its seed projects in South Asia recommend the break-up of state-owned seed monopolies, the removal of barriers to entry by private agents, elimination of subsidies to the public sector, and independent testing and certification processes (OED, 1995; OED, 1996).

3.25 Tripp & Louwaars (1997) make the important distinction between market liberalization and deregulation policies designed to stimulate the entry of private agents into seed markets. Liberalization entails privatization of state-owned seed monopolies, reduction of barriers to entry, and relaxation of germplasm and seed import restrictions, and has been pursued in a number of developing countries. Deregulation, on the other hand, is a far more complex issue: regulations designed for seed markets are often established to reduce information asymmetries, and changing the regulatory structure to support the private sector must be undertaken so as to protect systems that improve the transmission of information. An effective reform policy must focus on strengthening the ability of government agencies and private firms to execute and manage regulations such as standards for seed certification, packaging information, and other forms of information disclosure. Specifically, Tripp and Louwaars recommend (a) the reorganization of regulations for variety registration and performance testing, (b) shifting public regulatory agencies to technical and policy support, and (c) strengthening IPRs pertaining to plant and plant materials. Along the same lines, Gisselquist & Van Der Meer (2001) recommends that seed laws and regulations should facilitate market development by providing for seed quality certification, phytosanitary certificates for seed exports, plant variety protections (PVPs), and other forms of IPRs.

3.26 Regional case studies provide important evidence of the relationship between efficient seed markets and private sector investment in agricultural R&D. Kosarek et al. (2001) argue the importance of institutional changes to support efficient seed markets for hybrid maize in Latin America and the Caribbean region. Pray et al. (2001b) observe that seed industry reforms in India that began in the late 1980s have played an important role in increasing private sector R&D and expanding competition in India's seed markets. Using firm-level survey data from 1888 and 1996, they observe that the decline in restrictions on domestic and foreign investment, and on imported R&D in-puts, resulted in increased investment and competition in agricultural R&D. They further argue that the growth in private sector R&D investments could potentially lead to a productive reallocation of scarce public resources (a) from R&D on maize and sunflower to other crops such as wheat, pulses, oilseeds and rice, and (b) from applied to basic research, thereby generating spillovers valuable to the private sector. During the same period in India, Morris et al. (1998) observe significant increases in private investment in maize research and competition from private sector entrants into the maize seed market. Tripp & Pal (2001) observe a similar trend in rice markets in Andhra Pradesh, notable in part because these private seed firms are marketing open-pollinated rice varieties.

3.27 In sub-Saharan Africa, the relative absence of a commercial seed sector, and the related issue of low adoption rates of new plant varieties, is attributable to a number of persistent policy issues common to many countries in the region (Tripp & Rohrbach, 2001). Regulatory policy regimes across the region favor state-owned enterprises and inhibit commercial entry into the seed sector. For instance, policy regimes that govern the testing, approval and release of new varieties often favor varieties produced by the national research systems over foreign varieties or varieties developed by the private sector. Many such regimes also possess limited resources and capacity to conduct services for private sector firms looking to bring new varieties to market.

3.28 Seed produced by state-owned firms continue to dominate seed markets with effective monopoly power, despite poor cost recovery, high costs to agrarian producers, and limited varietal offerings. Discussions over regional harmonization of regulatory regimes for agricultural seed, designed at reducing non-tariff barriers and promoting larger, more accessible markets for private firms has met with resistance in regions such as southern and eastern Africa. These problems are exacerbated by free seed distribution programs in times of crisis that often persist even once the crisis has subsided, often providing seed of unknown or inappropriate quality. Moreover, even when such programs turn to private sector firms from which to purchase seed, they tend to centralize purchasing through government or relief agencies, thereby discouraging the development of wholesale and retail trade channels. Policy options designed to expand private sector investment in agricultural R&D need to address key institutional and market deficiencies in sub-Saharan Africa. Apart from liberalizing regulations and markets dominated by the public sector, the region would stand to benefit from improvements in the linkages between public breeding programs and commercial seed production, distribution and marketing.

3.29 In sum, the incentives to private sector investment in agricultural R&D are contingent upon improvements in the institutional deficiencies relating to efficiency and information in seed and input markets. These improvements include strengthening testing and certification systems, consumer protection, farmer education, dissolution of state-owned monopolies, and other related strategies, and can only be accomplished with participation by both public and private actors. With a more constructive set of signals to private enterprise, agrarian producers may be able to better recognize and adopt new technologies, thereby increasing agricultural productivity and output.

4. Technology Transfers and Partnerships

4.1 Research on optimal forms of technology transfer comprises a vast literature. In the area of agricultural R&D, the most common pattern of private sector transfers is for multinational firms to develop a technology in an industrialized country and market it, directly or indirectly, in a developing country. Traxler (2001) identifies this mode of technology transfer as the “spillover benefits” approach, in which biotechnology firms located in industrialized countries conduct R&D leading to a new event and this technology is simply adapted by plant breeding firms for developing country markets. This approach requires relatively low scientific capacity in the developing country and characterizes the forms of technology transfer that have occurred in the private sector to date. A “targeted research” approach, on the other hand, requires a higher level of scientific capacity in the developing country. Under this approach, new technologies are developed and distributed to address issues specific to the agricultural context of a given developing country. To date, Traxler believes that there are no significant examples of this approach being undertaken. This raises the issue of whether new events will be based on technological innovations researched and developed in industrialized countries, the benefits of which may accrue to developing countries as spillovers but do not target the specific demands of the agricultural sector in developing countries.

4.2 The success of public-private partnerships and collaborations depend on (a) strong research programs and financial resources in both the public and private sector, (b) political support for public-private collaboration with domestic and foreign firms, and (c) an intellectual property rights regime that allows for commercial viability of different and diverse forms of public-private research initiatives (Pray, 2001).

4.3 Forms of public-private partnerships. To date, Traxler (2001) finds no tested model of public sector delivery of transgenic technologies in the developing world, with the exception of China (discussed separately, below). This observation implies that research, development, and introduction of new agricultural technologies will take form based exclusively on the private sector or a more innovative approach form that incorporates elements of public-private partnerships. Recent attention given to public-private partnerships warrants further examination.

4.4 Pray (2001) examines different forms of public-private partnership in agricultural R&D in a study of Brazil, China, and India. Such partnerships fall into one of five basic categories: basic and applied research initiatives led by the public sector (“co-financing”); outsourcing of private sector research to public institutions (“contracting”); joint public-private ventures in applied research (“joint venturing”); public partnerships with research foundations established by the private sector (“non-profit institutions”), and technology transfers between the public sector and private sectors (“technological transfer systems”). The success of these collaborations depend on (a) strong research programs and financial resources in both the public and private sector, (b) political support for public-private collaboration with domestic and foreign firms, and (c) an intellectual property rights regime that allows for commercial incentives within public-private research initiatives.

4.5 The first type of collaboration (co-financing) is represented in Brazil by the establishment of a virtual genomics institute by the State of Sao Paulo Research Foundation (FASESP). The institute, known as the Organization for Nucleotide Sequencing and Analysis (ONSA) is a three year project in basic biotechnology research that was established with a \$15 million investment from FASESP. By design and choice of project, ONSA is able to attract support and resources from the private sector. A variation on this theme is the establishment of commercial subsidiaries or projects by public agencies, such as seed companies, nurseries and unrelated commercial ventures established by regional research institutes in China, or China’s Transgene Corporation Ltd., established by the Biotech Research Institute of the Chinese Academy of Agricultural Sciences (Pray, 2001).

4.6 The second type of collaboration (contracting) occurs where private firms or cooperatives contract universities, laboratories, or individual scientists to conduct research. In Brazil, the Cooperative of Cane, Sugar and Ethanol Producers of the State of Sao Paulo (COPERSUCAR) has hired faculty from local universities, as well as universities in the U.S. and Australia, to develop a transgenic sugarcane variety with virus-resistant properties. In India, private firms have frequently hired plant breeders from public agencies who bring with them information and knowledge on improved plant varieties (Pray, 2001). AgrEvo/Plant Genetic Systems (PGS) has conducted collaborations with the Brazilian Agricultural Research Corporation (EMBRAPA, a public institution), the International Rice Research Institute (IRRI) in the Philippines, and the International Potato Center (CIP) in Peru to train staff from the public and

international agencies. Exploitation of intellectual property rights were allocated in the latter two partnerships such that PGS obtained exclusive rights for industrialized countries and non-exclusive rights for developing countries, while IRRI and CIP obtained non-exclusive rights for developing countries (CGIAR, 1999).

4.7 The third type of collaboration is characterized by joint ventures between private sector, typically multinational firms, and public sector institutions. In Brazil, Monsanto and EMBRAPA have entered into a joint venture on development of transgenic soybean. EMBRAPA supplies the soybean varieties and Monsanto provides the desirable gene sequences, while both collaborate on the transformation technology. Distribution of the transgenic soybeans will be conducted through Monsanto's commercial networks in Brazil, and royalties from sales will accrue to EMBRAPA to fund research into sustainable soybean production. In China, such collaborations work in different directions: one foreign firm (RiceTec, a U.S. company) is working with a public agency (the Hynan Hybrid Rice Research Center, which holds a U.S. patent on a hybrid rice production system) to improve grain quality and breeding techniques. Other foreign firms work with public agencies to develop plant breeding programs to supply seed markets in China, utilizing foreign cultivars owned and introduced by the foreign firm. To date, however, there is limited progress on this front (Pray, 2001).

4.8 The fourth type of collaboration (non-profit institutions) emphasizes the growing role of research foundations established and funded by the private sector. Because of their non-profit status, many of these foundations serve as important conduits for technology transfers and R&D investment between the public and private sectors. Research foundations are able to receive money from government agencies and private sector firms alike to undertake research projects and contract other public agencies and private firms to conduct research on their behalf. In India, the Indian Council of Agricultural Research (ICAR), a public sector institution, received funding from the Maharashtra Hybrid Seed Company (MAYCO) Foundation for hybrid rice research, while the MAYCO Foundation itself has received funds from ICAR and the Rockefeller Rice Biotechnology Network for other research projects (Pray, 2001).

4.9 The fifth type of collaboration describes a variety of mechanisms through which technologies are transferred between public agencies and private firms. Certain mechanisms are based on public sector releases of technologies to private sector firms in exchange for some form of remuneration, such as royalties or flat fees. In Brazil, EMBRAPA leads a consortium of 28 private seed companies for the transfer of hybrid maize. EMBRAPA is compensated for the technologies with royalties based on sales of each firm. Other mechanisms rely on the establishment of patent offices and systems to ensure disclosure and availability of information to both private and public agents on new agricultural technologies, processes and products (Pray, 2001).

4.10 The unique approach to public-private partnerships in China is worth mentioning as distinct from much of the discussion set forth above. Surveys by Huang et al. (2002) and Pray et al. (2001a) indicate that agricultural R&D in China is pursuing new biotechnologies in a pattern quite distinct from other developing countries. With support from large public sector R&D institutions and commercial spinoffs set up by R&D institutions, China is quickly expanding its plant biotechnology capacity, rapidly

introducing Bt cotton, and testing a wide range of transgenic crops including rice, wheat, potatoes, and peanuts.

4.11 At an international level, the CGIAR and representatives of the private sector continue to discuss many of the key issues posed by changing roles and relationships in agricultural R&D. This relationship is formalized through the CGIAR's Private Sector Committee (PSC), a 12-member body established in 1995 and comprised of representatives from MAR and companies of varying sizes from various countries. Private sector representation is based on firms with interests in agricultural R&D, biotechnology, agribusiness, fertilizer, crop protection, seeds, animal production, forestry, and fisheries. The (PSC) was established to identify R&D priorities in developing countries; private sector strategies that respond to these needs; the potential for cooperation between the CGIAR and private sector; and identification of mutually beneficial collaborative programs and partnerships that address food security issues (CGIAR, 2002).

5. Policy Issues

5.1 In this section, we discuss some of the issues that are central to an analysis of the private sector's growing role in agricultural R&D. These issues point to the priorities for future consideration and research.

5.2 *Private sector domination?* Although private sector investment in agricultural R&D is increasing while public sector expenditure is declining or stagnating in many developing countries, few observers believe that the former is poised to replace the latter any time soon. Even where private sector incentives are strengthened, the complementarity between private and public R&D will likely remain an important element for private sector growth (Pardey & Beintema, 2001). Public expenditure on agricultural R&D is an important source of basic research for private firms and a provider of technologies for which the costs are prohibitive or the returns too low or protracted for the private sector. Yet this does not immediately imply that the solutions to agricultural issues faced by developing countries will necessarily be generated by the inherent complementarities of the public and private sectors, even where institutions and markets are supportive. Hence the attention given in the literature to public-private partnerships and innovative approaches to facilitating more of these relationships.

5.3 Preconditions for new modes of agricultural R&D. Assuming that the mode of entry by private firms into agricultural R&D follows the predominant model described by Traxler (2001), certain preconditions must be met for countries to reap the benefits of technological spillovers. First, a functioning biosafety regulation process must be in place to facilitate the testing and approval of new varieties introduced by private firms. Second, countries must invest in improving seed markets to produce and distribute seed and information to agrarian producers. Third, countries must improve IPR regimes to generate incentives for the private sector to engage in R&D.

5.4 But if public institutions and private firms in individual developing countries are to generate targeted technological events specific to their agricultural requirements, a spectrum of cooperative relationships and institutional innovations must be pursued,

according to Traxler (2001). Apart from public-private partnerships in the forms discussed earlier, a targeted research approach would benefit greatly from regional cooperation between national agricultural research systems and continued involvement of the CGIAR. The specific role of the CGIAR is an important consideration in this context.

5.5 *Developing a high payoff model.* A synthesis of the approaches suggested by Traxler (2001) spillover benefits and targeted research requires a number of key institutional and market transformations. In short, a synthesis approach would promote private sector technological innovation through market incentives alongside a complementary and cooperative relationship with the public sector. To effect such a regime, improvements in seed market efficiency are critical, implying liberalization of seed markets, privatization of state-owned seed firms, improvements in regulatory frameworks and capacity, and improvements in the flow of information from seed producers and distributors to farmers. A second priority is the continued contribution of national agricultural research systems and the CGIAR in plant breeding and biotechnology through a negotiated and innovative process of “free riding” off private sector spillins. Related to this is the issue of strengthening IPR regimes while concurrently generating precedents for IPR sharing between public institutions and private firms. A third priority is promotion of government initiatives and programs to improve biosafety regulations and testing and approval procedures (Traxler, 2001). In sum, any interface between public R&D systems and private sector firms requires fundamental improvements in both public sector resource allocation and the development of market infrastructure to support commercial participation (Tripp & Rohrbach, 2001).

6. Conclusions

6.1 Based on the brief survey presented here, we are able to make the following observations about the role of the private sector in agricultural R&D in developing countries. First, as the growth rate of private sector investment in agricultural R&D increases and public sector expenditure declines, the market and institutional environment in which these forces interact is rapidly changing. Increasingly open and competitive markets are likely to further encourage private sector entry, but further gains from agricultural R&D will not arise exclusively from the private sector. Currently, private sector contributions to agricultural R&D are limited in terms of the specific crops, traits, countries, and technologies being pursued. This argues for continued public sector expenditure on R&D to fill the gaps in basic research or to facilitate research that targets the specific agricultural needs of developing countries. In this context, the future contributions of both the public and private sector are closely related to the pursuit of new and innovative approaches to public-private partnerships.

6.2 Based on these observations, further research may be required on the following:

- Identifying technologies that are needed to address specific agricultural issues faced by developing countries, and determining how to most effectively support development of these technologies through both private and public sector R&D.

- Investigating the effects of increasing industry concentration among multinational R&D firms on output, economic welfare and pricing.
- Evaluating reforms and liberalization in seed and input markets in the developing world, and determining whether reforms are improving incentives to both foreign and domestic firms.
- Assessing the potential contribution of new and innovative partnerships between the public and private sectors, and whether market and institutional arrangements can foster additional partnerships.
- Assessing the role that the MAR can play in fostering such partnerships and innovations.

Annex 1. References

- Alston, J. M., Chan-Kang, C., Marra, M. C., et al. (2000). A Meta-Analysis of Rates of Return to Agricultural R&D: Ex Pede Herculem? International Food Policy Research Institute, Washington, D.C.
- Consultative Group on International Agricultural Research (1999). Report of the Tenth Meeting of the CGIAR Private Sector Committee, Hattersheim, Germany, March 11-12, 1999. Meeting Report, Consultative Group on International Agricultural Research, Washington, D.C.
- Consultative Group on International Agricultural Research (2002). CGIAR Private Sector Committee Terms of Reference. Technical Report, Consultative Group Oil International Agricultural Research, Washington, D.C.
- Echeverria, R. G. (1991). Impact of Research and Seed Trade on Research Productivity. In P. Pardey, J. Roseboom, and J. R. Anderson, editors, *Agricultural Research Policy: International Quantitative Perspectives*, pages 365-395. Cambridge University Press, Cambridge, U.K.
- Evenson, R. E., Pray, C. E., & Rosengrant, M. (1999). *Agricultural Research and Productivity Growth in India*. Research Report 109, International Food Policy Research Institute, Washington, D.C.
- Fernandez-Cornejo, J. & McBride, W. (2000). Genetically Engineered Crops for Pest Management in U.S. Agriculture. Agricultural Economics Report 786, Economic Research Service, U.S. Department of Agriculture, Washington, D.C.
- Fulton, M. & Giannakas, K. (2001). Agricultural Biotechnology and Industry Structure. *AgBioForum*, 4(2), 137-151.
- Gisselquist, D. & Van Der Meer, C. (2001). Regulations for Seed and Fertilizer Markets: A Good Practice Guide for Policy Makers. Rural Development Working Paper 22817, World Bank, Washington, D.C.
- Huang, J., Rozelle, S., Pray, C., & Wang, Q. (2002). Plant Biotechnology in China. *Science*, 295(5555), 674-677.
- International Seed Trade Federation and International Association of Plant Breeders (2002). FIS and ASSINSEL, World Seed Industry Organizations.
- International Service for the Acquisition of Agri-biotech (2002). International Service for the Acquisition of Agri-biotech.
- James, C. (2001a). Global Review of Commercialized Transgenic Crops: 2001. ISAAA Briefs 24, International Service for the Acquisition of Agri-biotech, Ithaca, N.Y.
- James, C. (2001b). Global Status of Commercialized Transgenic Crops: 2000. ISAAA Briefs 23, International Service for the Acquisition of Agri-biotech, Ithaca, N.Y.
- James, C. & Krattiger, A. F. (1996). Global Review of Field Testing and Commercialization of Transgenic Plants, 1986-1995: The first decade. ISAAA Briefs No. 1, International Service for the Acquisition of Agri-biotech, Ithaca, N.Y.
- Kalaitzandonakes, N. & Bjornson, B. (1997). Vertical and Horizontal Coordination in the Agro-Biotechnology Industry: Evidence and Implications. *Journal of Agricultural and Applied Economics*, 29(1), 192-39.
- Kosarek, J., Garcia, P., & Morris, M. (2001). Factors Explaining the Diffusion of Hybrid Maize in Latin America and the Caribbean Region. *Applied Economics*, 26(3), 267-280.

- Morris, M., Singh, R., & Pal, S. (1998). India's Maize Seed Industry in Transition: Changing Roles for the Public and Private Sectors. *Food Policy*, 23(1), 55-71.
- Morris, M. L. (1998). *Maize Seed Industries in Developing Countries*. CIM-MYT, Boulder, CO.
- Operations Evaluation Department, World Bank (1995). *Bangladesh, India, and Pakistan Seed Projects*. OED Project Evaluation, Operations Evaluation Department, World Bank, Washington, D.C.
- Operations Evaluation Department, World Bank (1996). *The Seed Industry in South Asia*. *Precis & Briefs*, Operations Evaluation Department, World Bank, Washington, D.C.
- Organisation for Economic Cooperation and Development (1994). *Biotechnology and Sustainable Agriculture: Lessons from India*. OECD Working Paper.
- Papers 103, 11(87), Organisation for Economic Cooperation and Development, Paris.
- Pardey, P. G. & Beintema, N. M. (2001). *Slow Magic: Agricultural R&D a Century After Mendel*. Technical Report 36, Agricultural Science and Technology Indicators/International Food Policy Research Institute, Washington, D.C.
- Pray, C. Ma, D., Huang, J., & Qiao, F. (2001a). Impact of Bt Cotton in China. *World Development*, 29(5), 813- 825.
- Pray, C., Ramaswami, B., & Kelley, T. (2001b). The Impact of Economic Reforms on R&D by the Indian Seed Industry. *Food Policy*, 26, 587-598.
- Pray, C. E. (2001). Public-Private Sector Linkages in Research and Development: Biotechnology and the Seed Industry in Brazil, China, and India. *American Journal of Agricultural Economics*, 83(3), 742 747.
- Pray, C. E. & Fuglie, K. (2001). *Private Investment in Agricultural Research and International Technology Transfer in Asia*. Agricultural Economics Report 805, Economic Research Service, U.S. Department of Agriculture, Washington, D.C.
- Ribeiro, S. (1998). *Private Research, Social Benefits and Public Policy: The Case of Hybrid Sorghum and Pearl Millet in the Indian Seed Industry*. M.S. Thesis, Department of Agricultural Economics, Rutgers University, New Brunswick, N.J.
- Traxler, G. (2001). *Biotechnology in a Complete System of Genetic Improvement: A Perspective on Developed and Developing Countries*. International Food Policy Research Institute Seminar Series, October 18, 2001, Washington, D.C.
- Tripp, R. (2001). Can Biotechnology Reach the Poor? The Adequacy of Information and Seed Delivery. *Food Policy*, 26, 249 264.
- Tripp, R. & Louwaars, N. (1997). *Seed Regulation: Choices on the Road to Reform*. *Food Policy*, 22(5), 433 446.
- Tripp, R. & Pal, S. (2001). The Private Delivery of Public Crop Varieties: Rice in Andhra Pradesh. *World Development*, 29(1), 103 117.
- Tripp, R. & Rohrbach, D. (2001). Policies for African Seed Enterprise Development. *Food Policy*, 26, 147 161.

Annex 2: List of Working and Background Papers, Authors, and Peer Reviewers

Working Papers

Barrett, Christopher B. 2002. *Natural Resources Management Research in the CGIAR: A Meta-Evaluation*.

Peer Reviewers: Jock Anderson, Derek Byerlee, Dana Dalrymple, Hans Gregersen, Ted Henzell, John Lynam, Vernon Ruttan, Meredith Soule, Joachim von Braun, Usha Barwale Zehr

Eicher, Carl K. and Mandivamba Rukuni 2002. *The CGIAR in Africa: Past, Present, and Future*.

Peer Reviewers: Malcolm Blackie, Dana Dalrymple, Bob Herdt, Alain de Janvry, Romano Kiome, John Lynam, Eric Tollens, Geoffrey Mrema, Wilfred Mwangi, Cyrus Ndiritu, Emmy Simmons, Moctar Touré

Gardner, Bruce 2002. *Global Public Goods from the CGIAR: Impact Assessment*.

Peer Reviewers: Jock Anderson, Dana Dalrymple, Osvaldo Feinstein, Paul William Glewwe, Hans Gregersen, George Norton, Scott Rozelle, Vernon Ruttan, Sara Scherr, Sudhir Wanmali

Lesser, William 2002. *Reviews of Biotechnology, Genetic Resource and Intellectual Property Rights Programs*.

Peer Reviewers: Ronnie Coffman, John Dodds, Robert Evenson, Brian Ford Lloyd, Anatole Krattiger, Steve Kresovich

Spielman, David 2002. *International Agricultural Research and the Role of the Private Sector*.

Macedo, Jamil, Marcio C. M. Porto, Elisio Contini, and Antonio F. D. Avila 2002. *Brazil Country Paper for the CGIAR Meta-Evaluation*.

Katyal, J.C. and Mruthyunjaya 2002. *CGIAR Effectiveness — A NARS Perspective from India*.

Background Papers (Available upon request)

Ndiritu, Cyrus 2002. *CGIAR-NARS Partnership: The Case of Kenya*.

Romano, Luis 2002. *Colombia Country Paper for the CGIAR Meta-Evaluation*.