Progressing Public-Private Sector Partnerships

in

International Agricultural Research and Development

Clive James
Chair, ISAAA Board of Directors

No. 4-1997

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Executive Summary

The world's population is currently 5.8 billion and is expected to almost double by the year 2050 when approximately 90 percent of the global population will reside in the countries of the South. Compounding this situation, the additional food will have to be produced on the existing area, or less, of agricultural land without degrading the fragile natural resource base. Thus, one of the major challenges facing the world in the 21st century will be to achieve food security without degrading the natural resource base. Agricultural research and technological improvements will continue to be pre-requisites for increasing crop productivity. Industrial countries have benefited from agricultural research and development (R&D) investments by both public and private sectors, whereas developing countries, by and large, have relied on less than adequate funding, principally from the public sector. In the future it is imperative that developing countries invest significantly more public sector funding in agricultural R&D and also encourage more private sector investments.

To meet the challenge of future global food security requires new partnerships between the public and private sectors in agricultural R&D and agribusiness; these partnerships will serve to optimize and integrate the respective comparative advantages of the partners in their quest to achieve mutual objectives. During the 1990s there has been a growing awareness in both public and private sectors of the significant benefits that can be derived from such public-private sector collaboration. This publication aims to present information that supports the need for public-private sector partnerships by reviewing public and private investments in agricultural R&D during the last decade, when there has been a decline in official development assistance to countries of the South. Three examples of public-private sector partnerships are presented to illustrate that there are opportunities for collaboration which result in win-win situations and contribute to global food security.

Recent estimates suggest that in the decade 1987 to 1997, official development assistance (ODA) to agriculture has declined by 50 percent. Furthermore during the same period, national governments have provided less support to agriculture in developing countries. This does not bode well for the future, which highlights the importance of developing new partnerships between the public and private sectors. It is noteworthy that public sector ODA funding for all sectors is $60 billion annually, whereas private sector investment from the North in the South is $170 billion per year, and growing, equivalent to almost three times that of the public sector ODA. In 1990 global investments in agricultural R&D by the public sector were estimated at $17.3 billion, with $8.8 billion invested by developing countries, and $8.5 billion by industrial countries. Industrial countries typically invest 2 percent of agricultural GDP in public R&D whereas the corresponding figure for developing countries is 0.5 percent, a quarter of the industrial country investment. In the 1960s in the United States, private sector R&D investments were 5 percent less than corresponding investments by the public sector; however, by 1995 private sector R&D investment was 27 percent more than that of the public sector. Whereas private sector investment in developing countries is lower than public sector R&D, the same trend is observed in countries such as Colombia where private sector R&D investment, expressed as a percentage of the national R&D investments, increased from 22 percent in 1970 to 37 percent in 1991.

Corporations involved internationally in agriculture are involved in a broad range of activities that include fertilizer, crop protection, seed industry, animal health and biotechnology. The scale of operations in each of these market areas is reviewed, and the major corporations characterized in terms of global revenues, R&D, and the structure of the global markets by region and product, using recent data for 1996. Industry considers 5 to 7 percent of revenue as the minimum investment necessary to ensure an acceptable level of competitiveness in the marketplace, and the average R&D investment for 15 crop protection and seed companies in 1996 was 10.6 percent. Whereas direct comparisons with the public sector are not possible, private sector R&D investments are judged to be considerably higher than those of the public sector.

The global fertilizer market in 1995/1996 was $50 billion, with the private sector responsible for at least half of the market. On a global basis 60 percent of fertilizer is consumed in developing countries, and more specifically 63, 61 and 48 percent of nitrogen, phosphate, and potash respectively, are used by developing countries. The crop protection global market was valued at $31.25 billion in 1996, with herbicides, insecticides, fungicides, and transgenic crops representing 48, 28, 19, and 1 percent respectively of the world market; it is noteworthy that the global market for transgenic seed increased from $75 million in 1995 to $235 million in 1996, an increase of 213 percent. Seventy-two percent of the world crop protection market is in industrial countries and 28 percent in developing countries. The major countries for crop protection products are the United States (28 percent), Japan (12 percent), and the major crops on which crop protection products are used are cereals (19 percent), followed by maize (12 percent), rice (11 percent), soybean (9 percent) and cotton (8 percent). The global area of commercial transgenic crops, where the dominant traits are herbicide tolerance, and insect or virus resistance, increased by a factor of 4.5 from 7.0 million acres (2.8 million ha.) in 1996 to 31.5 million acres (12.8 million ha.) in 1997.

The value of the seed industry is estimated at $45 billion per year, equally divided into three segments: commercial seed, farmer-saved seed, and seed supplied by Governments, a prevalent practice in developing countries and centrally planned economies. Consumption of agricultural seed, which includes farm-saved seed is 120 million tons per year. Asia and the Commonwealth of Independent States (CIS) are the largest consumers of seed. In recent years the global seed market has been relatively stagnant, except in Asia where consumption has increased by 18 percent, with rice representing one-third of the total seed used. Cereals dominate the global seed market, accounting for two-thirds of the 120 million tons, wheat (35 million tons) being the dominant crop. The top 25 seed corporations had a total revenue of $8 billion in 1996. The world market for animal health products in 1995/ 1996 was $14.4 billion, with pharmaceuticals representing just under half. Cattle account for 32 percent of the global animal health supplies, followed by pigs (23 percent), poultry (18 percent), and sheep (6 percent). Approximately 66 percent of the animal health market is in industrial countries with 34 percent in developing countries.

Many of the transnational corporations have parallel involvement in many of the sub-sectors; hence one corporation may have interests in areas that include fertilizer, crop protection, seed and animal health, and with biotechnology being a common denominator of increasing importance in R&D. The need to create the minimum critical mass in R&D and marketing has led to many mergers and alliances in the private sector; biotechnology has been the major factor that has triggered consolidation in the industry in recent years and this trend is likely to continue. Investments in biotechnology have been significant with an estimated $10 billion invested by the United States alone in biotechnology R&D in 1995, of which $2 billion was in agricultural biotechnology. The market for biotechnology products in the United States was estimated at $304 million in 1996, and the global market for transgenic crops is projected to reach $2 to $3 billion in the year 2000, $6 billion in 2005, and $20 billion in 2010.

There is no greater incentive for collaboration between the public and private sectors in agricultural research than the enormous challenge posed by global food security, which will require that limited resources be used in the most effective way to develop sustainable agricultural systems that also conserve natural resources. The significant investment of the private sector in biotechnology, perhaps more than any other single factor, has clearly demonstrated the need for, and significant advantages associated with collaboration between the public and the private sectors in agriculture. Global private sector investments in agricultural and food R&D are conservatively estimated at $11 billion in industrial countries, and $2 billion in developing countries, compared with $8.5 billion and $8.8 billion by the public and private sectors respectively, for a public/private global total of $30 billion.

It is evident that $30 billion in global investment for agricultural R&D is inadequate to meet future needs and it is, therefore, vital that the two major players, the public and private sectors, involved in agricultural R&D on the global scene collaborate to address the important and impending challenge of global food security. Governments of developing countries, the donor community, and the private sector must take the necessary and urgent steps to stimulate the building of partnerships. It is encouraging to note that there are several successful initiatives already underway to build new partnerships between the public and private sectors. Three of these public-private initiatives are the founding of the International Service for the Acquisition of Agri-Biotech Applications (ISAAA) in 1991, the establishment of the Private Sector Committee of the CGIAR in 1995, and the formation of a Public-Private Sector Consortium by CAB International in 1995 to support the development of a Global Electronic Compendium for Crop Protection. These three initiatives, which are quite different in character, are described in more detail in the text, and can serve as models for emulation and improvement in future public-private sector partnerships.

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Introduction

The world's population is currently 5.8 billion and is expected to almost double by the year 2050. Ninety-seven percent of this population increase will occur in developing countries in Africa, Asia and Latin America (Swaminathan 1995). Even with today's 5.8 billion population, 800 million people are deprived of adequate food supplies and 1.3 billion people, equivalent to 30 percent of the population of the developing world, live in abject poverty, and barely survive on one dollar per day or less, for food, shelter, and other essential needs. A high proportion of the poor people live in rural areas where the natural resource base is fragile and deteriorating. The challenge for the future is global food security, which will require at least a doubling or preferably tripling, of food production by the year 2050 to meet the needs of the rapidly growing population of up to 11 billion people, ninety percent of whom will reside in the developing countries of the South. Compounding the situation, this additional food will have to be produced on the existing area, or less, of agricultural land. The enormity of the challenge of food security is best illustrated by the fact that in the next fifty years the global population will consume twice as much food as has ever been consumed since agriculture began 10,000 years ago.

Agricultural research and technological improvements are, and will continue to be prerequisites for increasing agricultural productivity and generating income for farmers and the rural work force. This in turn will help to alleviate poverty, which is primarily a rural phenomenon, but also afflicts the urban poor; 75 percent of the poor in Africa and Asia live in rural areas. Given that economic growth is the best antidote to poverty, and that few countries have achieved economic growth without agricultural growth, it follows that agriculture, a principal sector in most developing countries, can contribute significantly to growth and development and should be accorded a high priority. During the last decade, however, investments in agriculture, at both the national and international levels, have declined. There is an urgent need to reverse this trend, which, if left unchecked, can threaten global food security.

Industrial countries have benefited from agricultural research and development (R&D) investments in both the public and private sectors, but developing countries have by and large relied on public sector support from national programs and from international organizations such as the international centers of the Consultative Group on International Agricultural Research (CGIAR). In the future it is imperative that developing countries invest significantly more public sector funding in agricultural R&D and also encourage the indigenous and international private sectors to participate in activities where they have comparative advantages. To meet the challenge of global food security requires new partnerships in agricultural R&D between the public and private sectors that optimize the comparative advantages of each in pursuit of mutual objectives. Forging these new public-private sector partnerships would promote the most effective use of limited global resources for the development of sustainable agricultural systems. In the last decade governments in industrial countries have encouraged increased participation by the private sector in agricultural R&D, a trend that is being mirrored in many developing countries. During the 1990s there has been a growing awareness, in both the public and private sectors, of the significant benefits that can be derived from such collaboration.

This publication is not an exhaustive analysis of public and private sector investments in agricultural R&D; rather, it presents general information that demonstrates the need for public-private sector partnerships, with particular emphasis on developing countries. In order to provide a global contextual framework in which to view the activities of the public and private sectors, the declining official development assistance to agriculture as well as public and private sector investments in agricultural R&D are briefly reviewed; for the latter, selected activities of the private sector active in international agricultural R&D are characterized. The need for collaboration between the private and public sector is discussed and three different initiatives are described that involve collaboration between the public and the private sectors, aimed at building new partnerships for the future.

Declining Support for Developing Country Agriculture

A recent International Food Policy Research Institute (IFPRI) study (Brown and Haddad 1994) reported that the proportion of official development assistance (ODA) devoted to agriculture decreased from 20 per cent in 1980 to 14 per cent in 1990. The study also showed that real external assistance to agriculture for developing countries declined from $12 billion[1)] in 1980 to $10 billion in 1990. More recent estimates (World Bank 1997) suggest that in the decade 1987 to 1997 official development assistance for agriculture has declined by 50 percent. Although there are many reasons for this decline, the following are believed to be the major factors. First, there are those within the development assistance community who (i) reject the view that investment in agriculture is a prerequisite for economic growth in developing countries, and (ii) contest the reported high private and social rates of return of 20 percent or more attributed to agricultural research projects. Second, during the 1980s and 1990s, bilateral and multilateral agencies that provided development assistance, assigned a higher priority to environmental protection, which reduced the amount of funds available for support to agriculture. This change in priority occurred at the same time donor agencies were being forced to deal with their own domestic economic constraints. Consequently, donors were unable to satisfy all of the new and competing demands, such as significant financial aid to Eastern Europe and the countries of the former Soviet Union.

In the past, ODA and official investment assistance have been important for obtaining additional financial support from national programs for agricultural research. There is now evidence that this external support is declining at the same time developing countries are providing less support to agricultural R&D. External assistance to national agricultural research systems (NARS) is estimated to be 35 percent for Sub-Saharan Africa, 26 percent for Asia and the Pacific, and 7 percent for Latin America and the Caribbean. The breadth of support for agriculture from the donor community tends to be narrow and, therefore, is vulnerable. For example, the World Bank provides 25 percent of the total agricultural R&D support to developing countries, and two thirds of the World Bank's $817 million to developing countries during the period 1981 to 1987 was limited to six projects (Anderson *et al.* 1994). One positive development is the World Bank's revitalized Rural Development Program which increased lending to $3.9 billion for 56 projects in 1997, after several years of decline. Similarly the International Finance Corporation's financing of food and agri-business continued to grow in 1997 to $814 million for 27 projects (World Bank 1997).

In summary, declining support of public sector funds from ODA to aid agricultural research in developing countries does not bode well for the future, which highlights the importance of increased participation by the private sector in partnership with the public sector. It is noteworthy that public sector ODA funding for all sectors is currently estimated at approximately $60 billion annually, whereas private sector investments from the North for all sectors in the developing countries of the South are estimated at more than $170 billion per year (Serageldin and Sfeir-Younis 1996), equivalent to almost three times that of public sector ODA.

Public Sector Investments in Agricultural R&D

In the 1960s industrial countries accounted for approximately two-thirds of the total public sector investments in global agricultural research. It was not until 1990 that developing countries invested marginally more than industrial countries in agricultural R&D. In 1990 global investments in agricultural R&D by the public sector were estimated at $17.3 billion, with $8.8 billion invested by developing countries and $8.5 billion by industrial countries (Alston and Pardey 1996).

One of the most useful and meaningful methods for comparing national agricultural research expenditures is to express them as a percentage of the corresponding national agricultural gross domestic product (GDP); Anderson *et al.* (1994) reported these as "agricultural research intensity ratios". Data for the period 1961 to 1993 is shown in Table 1.

1) All data in this publication are given in US dollars ($).

Table 1: Investments in Agricultural R&D
(expressed as percentage of national agricultural GDP)

Region or Country	Number of Countries	1961-65	1971-75	1981-85	Most Recent Year
Developing Regions					
Sub-Saharan Africa, (excluding South Africa)	17	0.42	0.67	0.76	0.58[a]
South Africa	1	1.39	1.53	2.02	2.59[a]
Asia and the Pacific (excluding China)	15	0.14	0.22	0.32	---
China	1	0.57	0.44	0.42	0.42[b]
Latin America and the Caribbean	26	0.30	0.46	0.58	---
West Asia and North Africa	13	0.28	0.50	0.52	---
Developed Countries	18	0.96	1.41	2.03	---
United States	1	1.32	1.36	1.93	2.22[c]
Australia	1	1.54	3.56	4.52	4.42[d]

[a]1991 estimate, [b]1993 [c]1992 [d]1988.
Source: Pardey and Alston, (1995).

The data in Table 1 indicate that industrial country investments show continued growth, with at least 2 per cent of agricultural GDP invested in R&D by the early 1980s; the average investment by eighteen industrial countries in the early 1980s was 2.03 percent, with the United States reporting 2.22 percent in 1992 and Australia 4.42 percent in 1988. Corresponding developing country expenditures averaged approximately 0.5 percent in the early 1980s, equivalent to one-fourth of the amount invested by industrial countries. Whereas public sector investments in agricultural R&D in developing countries doubled on average between the 1960s and the early 1980s, the initial rapid growth during the early 1960s slowed during the 1970s, and by the 1980s investments had either leveled off (China at 0.42 percent) or declined, with seventeen Sub-Saharan Africa countries showing a significant decrease, from 0.76 percent in 1981 to 1985, to 0.58 percent in 1991. It is noteworthy that the Republic of South Africa's investment in agricultural research continued to increase, from 1.39 percent in the 1960s to 2.02 percent in the early 1980s, to 2.59 percent in 1991, and compared favorably with investment in industrial countries such as the United States, which reported 2.22 percent for 1992.

In summary, recent global investments in public agricultural research show that developing countries invest approximately 0.5 percent of agricultural GDP in agricultural R&D, one-fourth of the amount invested by industrial countries, which average 2 percent. The significant growth in public spending on agricultural research in the 1960s in developing countries has leveled off or declined in some countries, and there is growing concern that current investments will not be adequate for delivering the technology contribution necessary to increase food productivity sufficiently to ensure food security in the future. Given that global resources devoted to agricultural R&D are inadequate, one of the options that must be explored is better use of current allocated global resources, including the integration of public and private sector research resources, so that limited global resources can be used to achieve mutual objectives more effectively and efficiently at the national and international levels.

Private Sector Investments in Agricultural R&D and Estimates of Global Markets for Selected Products

There are no comprehensive and uniformly generated global estimates of private sector investments in agricultural R&D for industrial and developing countries. However, some data from selected industrial countries, where most of the private sector investments are made, provide an indication of the scale and scope of investment *vis-a-vis* the public sector. In the early 1960s private sector agricultural R&D expenditures in the United States were about $250 million annually, approximately 5 percent less than corresponding public sector expenditures. Recent estimates (United States Department of Agriculture 1995) for the United States indicate that in-house private sector agricultural research expenditures for 1992 were $3.3 billion, 27 percent more than the corresponding amount spent by the U.S. public sector. The data in Table 2 show the trends in private sector spending for various activities during the period 1960 to 1992. It is noteworthy that private sector agricultural R&D spending in the United States increased almost twenty-fold during this period, with real expenditures (expressed in 1980 dollars) increasing by a factor of three, from $511 million in 1960 to $1,648 million in 1992 (Alston and Pardey 1996). During the 1960s and 1970s, spending on agricultural research by the private sector showed real growth rates of more than 4.5 percent per year and exceeded corresponding public sector spending. Despite the fact that U.S. private expenditures in agricultural R&D grew at lower real growth rates in the 1980s, compared with the 1960s and 1970s, the total investment by the U.S. private sector in 1992 was $700 million greater than the public sector. The highest rate of growth in the 1970s was in chemicals, which was also the only activity to decline in the 1980s, when postharvest and food processing investments increased rapidly from $456 million in 1982 to $1,088 million in 1992.

Although available data do not allow precise comparisons and breakdown of public and private sector spending in agricultural R&D, the trend in the United States - higher spending in the 1970s and 1980s by the private sector compared with that of the public sector - is probably representative of the spending in most other industrial countries. Comparable data for agricultural and food R&D in the United States, United Kingdom, and France for the mid-1980s indicate that annual private sector expenditures were $2,400 million, $530 million and $270 million, respectively, equivalent to 49, 47, and 39 percent of total spending by both the public and private sectors (Anderson 1996), and these percentages are likely to have increased significantly in the interim period.

Expenditures on agricultural R&D by the indigenous and international private sectors in developing countries are much lower than in industrial countries and are concentrated in a few of the larger and more advanced developing countries, such as Argentina, Brazil, India, and

Table 2: Trends in Private Sector Spending on Agricultural R&D: Input-Oriented, Postharvest and Food Processing, 1960 to 1992
(millions of current dollars)

Year	Input-Oriented				Postharvest & Food Processing	Total	
	Chemicals	Agricultural machinery	Veterinary/ Pharma-ceuticals	Plant breeding		Current	Real
1960	9.7	75.9	6.0	5.6	80.0	177.2	511.9
1970	126.0	89.1	45.0	26.3	206.1	492.5	839.0
1980	1,390.0	287.0	111.0	96.7	456.1	1,340.8	1,340.8
1992	1,123.0	394.0	306.0	399.7	1,088.0	3,310.7	1,648.0

Source: Adapted from United States Department of Agriculture (1995).

Mexico (Pray and Echeverria 1991). More recent data (Falconi 1992, 1993) show that in the 1970s and 1980s private sector investments in agricultural R&D in some developing countries increased faster than public sector investments, similar to the trend in the United States. For example, private sector investments (expressed as a percent of total R&D expenditures) in Colombia, increased from 22 percent in 1970 to 37 percent in 1991, and in Ecuador from 19 percent in 1986 to 27 percent in 1991. This trend is not surprising because it occurred at a time when many developing countries introduced policies to encourage increased participation by the private sector in agricultural R&D.

Given the nature of the market place and the competition among private sector corporations, comprehensive data on agricultural R&D is not readily available in the public domain. However, much can be gleaned about the scale and scope of private sector activities in an international context. In this paper, 1996 data from industry sources has been used to characterize the international markets for selected products, and to estimate R&D expenditures, expressed as a percentage of revenues. These activities are discussed in the following section.

Activities of the Private Sector in International Agricultural R&D

Corporations active in international agricultural research include a large number of companies from the North and fewer, but an increasing number of, indigenous companies from the South. The companies from the North range in size from small corporations, often with specialized applications and operations in one or few industrial countries, to large transnationals with global operations in many industrial and developing countries. Companies from the South are generally smaller and focus on their home country or region. Recent acquisitions - the successive acquisitions by Seminis of the Empresa La Moderna-ELM (Pulsar) Group from Mexico of Asgrow Seed, Peto Seed, Royal Sluis, and DNAP - however, indicate that some of the larger companies from the South are expanding their base of activities and becoming transnational.

The private sector has broad-ranging activities in agricultural research focused on the development, production, and distribution of products and services that lend themselves to commercialization. The private sector's major activities are in the industrial countries where currently there are more opportunities for commercialization than in developing countries, but this is changing. Most private sector activities in the developing world take place in the most advanced developing countries and favor working with large and wealthy commercial farmers and plantations rather than with small, subsistence, and resource-poor farmers. The corporations from the North and South that are active in agricultural R&D and are potential partners for public sector institutes are engaged in very diverse activities, some of which are listed below:

- acquisition, exchange, distribution and improvement of genetic stocks of crops, forest species, livestock and fish, using conventional and biotechnology applications;
- production and distribution of improved seed and livestock to meet international needs;
- production of fertilizers and development of management practices to optimize crop production;
- development of diagnostics to detect diseases in crops, animals, and fish;
- production of pesticides and pesticide application within the context of chemical control or integrated pest management;
- development of strategies to ensure responsible deployment of resistance genes in crops that will optimize durability of the genes;
- development and production of vaccines and other disease control agents for animal diseases;
- processing, storage, and use of food and feed products, including control of post-harvest losses;
- global strategic planning and policy analysis aimed at developing commercial agriculture-based products to meet global needs;

Private sector activities in agricultural research, such as those listed above, are conducted by industry groups that can be conveniently classified according to the following product types:

- fertilizers;
- seeds;
- crop protection;
- crop and microbial biotechnology products;
- animal genetic stocks, including biotechnology-based technologies;
- animal health products;
- food and food processing;
- forestry;
- fisheries;
- machinery and equipment.

The above classification, based on product groups, can be used to match and compare the activities of the private sector with those of the public sector. To provide an indication of the scale of the private sector’s international activities, recent data on global markets for selected major industry groups have been collated, with major companies identified and listed according to their estimated global markets or their estimated R&D expenditures. Data have been collated for fertilizers, seeds, crop protection, animal health, and biotechnology. Many of the large transnational companies are listed in several of the groups, indicating that they are involved in several areas; for example, some companies have operations in seeds, agricultural chemicals (pesticides), as well as in crop and animal biotechnology.

Estimates of R&D Expenditures for Selected Corporations

The data in Table 3 list 1996 annual revenues and R&D expenditures for selected agricultural companies in crop protection and in seeds; the intent is to provide a better understanding of the scale and scope of current R&D expenditures by the private sector. R&D expenditures range from 14.8 percent of total revenue, to 5.9 percent, with an average of 10.6 percent. In general, industry considers 5 to 7 percent of revenue as the minimum investment necessary to ensure an acceptable level of competitiveness in the market place. Estimates of R&D expenditures by indigenous companies in developing countries suggest that on average R&D expenditures as a percentage of revenue are significantly lower, ranging from 1 to 5 percent, as compared with 5 to 10 percent or more in industrial countries. Whereas the percent R&D expenditure data in Table 3 cannot be compared directly with corresponding spending by the public sector on R&D, it is judged that percent R&D expenditures in the private sector are considerably higher than in the public sector.

Table 3: Annual Revenue and R&D Expenditures in 1996 for Selected Crop Protection and Seed Corporations (US$ millions)

Company	Annual Revenue	R&D Expenditure	Expressed as Percent of Revenue
Crop Protection Corporations			
Novartis	4,175	373	8.9
Monsanto	2,872	170	5.9
Zeneca	2,849	260	9.1
DuPont	2,515	258	10.3
AgrEvo	2,451	283	11.6
Bayer	2,305	305	13.2
Rhone-Poulenc	2,174	174	8.0
DowElanco	2,005	210	10.5
Cyanamid	1,989	165	8.3
BASF	1,506	184	12.2
Seed Corporations			
Pioneer	1,600	133	8.3
Novartis	970	122	12.6
Limagrain	660	60	9.1
Advanta	470	53	11.3
DeKalb	387	41	10.6
Seminis	380	47	12.4
KWS	350	47	13.4
Cargill	250	37	14.8

Source: For Crop Protection Corporations: Wood Mackenzie 1997. For Seed Corporations: compiled by Clive James 1997.

Fertilizer Industry

The annual global fertilizer market was estimated at $50 billion in 1995/96, as shown in Table 4, with nitrogen at $35 million representing the major component in terms of value and tonnage, followed by phosphate at $11.2 million, and potash at $4.0 million. Data in Table 5 show that developing countries use 63 percent of the nitrogen consumed on a global basis, 61 percent of phosphate, but only 48 percent of the potash. On average about 60 percent of global fertilizer is consumed in developing countries, and the private sector is responsible for at least half of the total global production. Due to significantly higher prices in 1995/1996, the global fertilizer market was estimated at approximately $50 billion. The major fertilizer producers active in the international market are listed in Table A-1 of the Appendix.

Doubling food production will require significantly more use of fertilizers despite the significant effort underway to develop crop varieties that are more responsive to fertilizers. Such increased use of fertilizer will exacerbate a situation that is already of environmental concern; that is, even with the current usage rate of fertilizer, intensified agriculture is resulting in nitrate levels in groundwater well above accepted tolerance levels. Various technologies are being investigated to determine the potential for increasing the efficiency of nitrogen utilization and for using nitrogen-fixing organisms to develop cereals that can fix some of their own nitrogen supply, thereby decreasing dependence on inorganic nitrogen. Use of mycorhiza is also being explored as a means to increase the extraction efficiency of phosphate and other elements that are not available in sufficient quantities for crops growing in marginal areas, such as acid soils.

Table 4: The Global Fertilizer Market (1995/1996)

Type of Nutrient	Millions of Tons	Annual Value* ($ Billions)
Nitrogen (N)	78.7	35.0
Phosphate (P_2O_5)	31.0	11.2
Potash (K_2O)	21.1	4.0
Total	**130.8**	**50.2**

***** Global value.

Source: International Fertilizer Development Center (IFDC) 1997

Crop Protection Industry

Global food, feed and fiber losses due to the combined effect of weeds, insect pests, and pathogens, are estimated to reduce yield by approximately 35 percent. The annual value of the global crop protection market in 1996 was $31.25 billion (Wood Mackenzie 1997). Herbicides represent 48 percent of the world crop protection market, insecticides 28 percent, fungicides 19 percent, growth regulators 4 percent, and transgenic seed less than 1 percent as shown in Table 6. The major difference between the global market in 1995 and 1996, and previous years, is the first commercialization of products derived from crop biotechnology, principally in North America; it is noteworthy that the global market for transgenic seed increased from $75 million in 1995 to $235 million in 1996 - an increase of 213 percent. Whereas herbicides are far more important than insecticides and fungicides in North America, Europe, and other industrial countries, with the exception of Latin America, insecticides predominate in developing countries. Approximately 72 percent ($22.6 billion) of the annual $31.3 billion global crop protection market is in

Table 5: Estimated Fertilizer Consumption in Industrial and Developing Countries 1995/1996
(million nutrient tons)

Nutrient	Industrial Countries	Developing Countries	Worldwide
Nitrogen (N)	28.8	49.9	78.7
Phosphate (P_2O_5)	12.0	19.0	31.0
Potash (K_2O)	12.1	9.0	21.1
Total	**52.9**	**77.9**	**130.8**

Source: International Fertilizer Development Center (IFDC) 1997 industrial countries of the North; 28 percent ($8.6 billion) is in developing countries of the South; note that this is a small change from 1994 when 25 percent of pesticides were used in developing countries. Nine countries consume 82 percent of pesticides, and the two major markets in the industrial North are the United States (28 percent) and Japan (12 percent), followed by several European Union countries and Canada, which consume 2 to 9 percent. Brazil and Argentina, at 6 and 3 percent respectively, are the only significant pesticide consumers from the South.

In terms of crops, horticultural crops (fruit and vegetables) are by far the most important, consuming just over 25 percent of pesticides, as shown in Table 7. The other major crops, which consume from 16 to 2 percent of the global supply are, in descending order of priority, cereals (small grains), maize, rice, soybean, cotton, sugar beet, and oil seed rape (canola). The segmented market for different pesticide products indicates that more insecticide (35 percent) is used on fruit and vegetables than any other crop category, followed in order of importance by cotton (19 percent), rice (13 percent) and maize (8 percent). The major use of herbicides is for cereals (19 percent), maize (18 percent), soybean (17 percent), fruit and vegetables (13 percent) and rice (9 percent). For fungicides, the major consuming crops are fruit and vegetables (46 percent), cereals (25 percent) and rice (15 percent).

Table 6: Global Crop Protection Market in 1996, by Group, by Principal Country and by Region

The Key Crop Protection Groups: 1995/1996

	Estimated Sales $ Millions		
Group	**1995**	**1996**	**% Change**
Herbicides	14,280	15,050	+5.4
Insecticides	8,750	8,745	-0.1
Fungicides	5,855	5,895	+0.7
Plant growth Regulators & Others	1,380	1,325	-4.0
Biotechnology Products	75	235	+213.3
Total	**30,265**	**31,250**	**+3.3**

Principal Countries' Percent Shares of the 1996 Global Crop Protection Market

USA	27.8
Japan	12.4
France	8.7
Brazil	6.2
Germany	4.0
Italy	3.3
Canada	2.8
United Kingdom	2.8
Argentina	2.8
Others	17.8
Total	**100.0**

Crop Protection Revenues 1996, by Region ($ millions**)**

	Herbicides	**Insecticides**	**Fungicides**	**Others**	**Biotech**	**Total**
North America	6,275	2,040	680	340	235	9,570
West Europe	3,605	1,420	2,510	600	0	8,135
East Europe	510	368	180	22	0	1,080
Japan	1,270	1,310	1,220	80	0	3,880
Industrial Countries	**11,660**	**5,138**	**4,590**	**1,042**	**235**	**22,665**
Latin America	2,035	1,005	520	140	0	3,700
Rest of East Asia	970	1,455	630	100	0	3,155
Rest of World	385	1,147	155	43	0	1,730
Developing Countries	**3,390**	**3,607**	**1,305**	**283**	**0**	**8,585**
Total	**15,050**	**8,745**	**5,895**	**1,325**	**235**	**31,250**

Source: Wood Mackenzie (1997)

Table 7: Global Crop Protection Market in 1996, by Crop, and by Crop Protection Product/Crop

Total Crop Protection Market by Crop	$ Million
Fruit and Vegetables	8,185
Cereals	4,955
Maize	3,655
Rice	3,380
Soybean	2,800
Cotton	2,639
Sugar Beet	827
Oilseed Rape/Canola	546
Others	4,263
TOTAL	**31,250**

Herbicide Market by Principal Crop	$ Million
Cereals	2,850
Maize	2,735
Soybean	2,590
Fruit and Vegetables	2,020
Rice	1,280
Sugar Beet	640
Cotton	600
Oilseed Rape/Canola	425
Others	1,910
TOTAL	**15,050**

Fungicide Market by Principal Crop	$ Million
Fruit and Vegetables	2,715
Cereals	1,490
Rice	870
Others	820
TOTAL	**5,895**

Insecticide Market by Principal Crop	$ Million
Fruit and Vegetables	3,070
Cotton	1,620
Rice	1,140
Maize	720
Others	2,195
TOTAL	**8,745**

Source: Wood Mackenzie (1997).

With the advent of biotechnology, some conventional insecticides are being substituted by novel genes - for example, *Bacillus thuringiensis (Bt)* - that confer resistance to insects through development of transgenic crops in which the active gene has been incorporated. In 1997, on a global basis, 9.9 million acres (4.0 million hectares) of transgenic crops resistant to insects were grown commercially. Similarly, 17 million acres (6.9 million ha.) of herbicide tolerant transgenic crops were grown in 1997 (James 1997). Currently, industrial countries consume considerably more herbicides than developing countries, but this is likely to change. Labor shortages and higher labor prices will lead to reduced use of hand-weeding for crops such as rice, and more herbicides will be applied, perhaps in conjunction with use of herbicide-tolerant varieties. Use of herbicides on rice in developing countries is likely to increase as the present trend to favor direct seeding in irrigated areas over traditional transplanting becomes more pronounced, and if more attention is focused on rainfed rice, where weeds are more of a problem. Water constraints associated with irrigated rice production will lead to less optimal control of weeds, which, in conjunction with the other factors noted above, could lead to significant increases in herbicide use on rice, more than 90 percent of which is grown and consumed in Asia.

Concern for the environment, large-scale commercialization of transgenic crops with resistance to insects, herbicides and plant pathogens, and widespread implementation of integrated pest management (IPM) are all factors that will likely have a significant effect on the structure of the crop protection market in the future. The private sector, however, will continue to dominate the crop protection market and will probably become more dominant as technologies become more sophisticated and as penetration of markets in the developing countries of Asia and Latin America, and to a lesser extent Africa, advances.

The principal companies involved in the international crop protection industry are transnationals with headquarters based in Europe (7), the United States (7), and Japan (9). Companies involved in crop protection are by and large also those involved in the chemical, pharmaceutical, seed and agribiotechnology industries. The principal companies involved and their respective share of the global market are listed in Table A-2 of the Appendix. The turnover of the companies ranges from $0.26 billion to $4.2 billion per year, and the leading ten companies account for approximately 80 percent of the $31.25 billion global market.

The crop protection industry has gone through a consolidation phase that featured mergers and takeovers, the most recent of which occurred in March 1996 with the merger of Ciba and Sandoz to form Novartis. Novartis, which will benefit from the combined pesticide markets of both Ciba and Sandoz, is now the largest crop protection company in the world, with sales of $4.175 billion in 1996 (see Table A-2). In 1995, Hoechst and Scherring merged to form AgrEvo, which is now ranked the fifth largest corporation involved in crop protection, with 1996 revenues of $2.5 billion. Whereas the incentive for the merger between Ciba and Sandoz was driven mainly by the needs of the pharmaceutical industry, it nevertheless has important implications for the crop protection industry, which is anticipating more mergers in the coming decade.

A survey of pesticide usage in the United States (Anonymous 1995) for the period 1991 to 1993 showed that use, as measured by volume of active ingredients, continued in 1993 a ten-year pattern of nearly flat growth, which was due to lower application rates of more potent compounds and more efficient use of pesticides. Twenty new active ingredients were registered in the United States in 1993, the highest number since 1975, with regulation costs estimated at $303 million or 3.6 percent of pesticide revenues.

Seed Industry

The value of the global seed trade is estimated at $45 billion annually, equally divided among the three different segments (Rabobank 1994): commercial seed, which is dominated by the private sector; farm-saved seed; and seed from government institutions. The latter is particularly prevalent in developing countries and in centrally planned economies. For example, in Africa, governments completely control the seed industry in 60 percent of the countries, and both the government and private sectors are active in 28 percent of the countries. Consumption of agricultural seed, which includes farm-saved seed, is approximately 120 million tons per year, and global consumption has been stable since about 1980. Asia and the Commonwealth of Independent States are the largest consumers of seeds, approximately 38.4 and 37.3 million tons respectively, in 1990, and together represent approximately two-thirds of the world market, as shown in Table 8. Consumption has been stagnant during the last decade, except in Asia, where consumption has increased by 18 percent since 1980; one-third of the seed used in Asia is rice.

Cereals dominate the world seed market, accounting for approximately two-thirds of the 120 million ton market, as shown in Table 9. Wheat is the major cereal crop for the seed market (35 million tons) followed by rice (13 million tons), barley (11.1 million tons), and maize (6.8 million tons); root and tuber crops are deceptively high, at 33.3 million tons, because of the high water content of "seed tubers". Of the $15 billion annual market in commercial seed, horticultural seed accounts for only $1.75 billion, and this includes both vegetable and flower seed. In 1990 approximately $13 billion of the $15 billion commercial seed market was in the OECD countries. The European Union ($5.8 billion), the United States ($4.5 billion), and Japan ($2.7 billion) were the largest markets; Turkey, Argentina, and Brazil were also important.

The private sector dominates the $15 billion annual global commercial seed market. There are approximately 1,500 seed companies worldwide, of which 600 are based in the United States and 400 in Europe. The twenty principal seed companies that are active internationally have a total market of $7.8 billion (Cailliez 1997) and are listed in Table A-3 and, with the exception of Empresas La Moderna, S.A.-ELM (Pulsar), which is based in Mexico, are transnationals based in the United States (5), Europe (12), and Japan (2). The annual turnover of the companies ranges from approximately $0.12 billion to $1.6 billion per year. Their combined turnover of $7.8 billion, is about half of the global commercial seed market. The market shares of these companies are expected to increase in the future. Of these 20 seed companies, approximately 75 percent are specialized seed companies, and the other 25 percent are owned by larger corporations with diversified interests.

Until the 1960s the seed industry comprised traditional seed companies that specialized in the improvement, pro-

Table 8: Total World Consumption of Agricultural Seed, by Continent
(millions of tons, incl. farm-saved seed)

Region	1980	1985	1990
Commonwealth of Independent States (CIS)	41.7	37.7	37.3
South America	4.3	4.4	4.2
Europe	23.2	23.6	21.3
North & Central America	10.9	10.4	11.0
Asia	32.6	35.0	38.4
Africa	3.9	4.3	4.6
Oceania	1.2	1.4	1.1
Total (World)	**118.8**	**117.7**	**118.7**

Source: FAO (Rabobank, 1994)

Table 9: Total World Consumption of Agricultural Seed, by Crop (millions of tons)

Crop	1980	1985	1990
Wheat	34.0	33.2	35.0
Barley	11.8	11.6	11.1
Rice	11.5	12.2	13.0
Maize	6.4	6.5	6.8
Other grains	9.5	9.3	8.9
Root/tuber crops	36.8	35.4	33.3
Pulses	3.4	3.9	4.0
Oilseeds	5.4	5.6	6.6
Total	**118.8**	**117.7**	**118.7**

Source: FAO (Rabobank, 1994)

duction and distribution of seed. During the late 1960s several transnational corporations with activities in farm chemicals and pharmaceuticals acquired seed companies to capture the range of products and services for the agricultural industry within one corporate structure, thus providing them with the necessary R&D critical mass and benefiting from economies of scale. After a decade or so, however, some of the transnationals sold their acquired seed operations, for several reasons: incompatibility with an evolving business strategy, lower margins than expected in seed operations where they lacked business linkages and experience, and a realization that the opportunities for using the seed industry to capture and market proprietary transgenic crops was a longer-term venture than they had anticipated. In the 1980s and 1990s acquisitions and mergers have resulted in fewer but larger seed companies, a trend that is expected to continue into the next decade, ultimately resulting in a few very large companies dominating the international market. This trend is fueled by the long-term investments in research that are necessary to ensure competitiveness and an international marketing structure to effectively compete in the global market.

Mergers and acquisitions are not the only way critical mass for R&D is being created in the industry. Collaborative arrangements, which range from cooperative R&D agreements to cross-licensing, are becoming prevalent, with Pioneer Hi-Bred International recently reporting that it has 800 agreements with various private and public organizations. In 1995, ELM (Pulsar) of Mexico acquired Asgrow Seed owned by Upjohn, added Peto Seed and Royal Sluis to its portfolio later in the year, and in early 1996 acquired DNAP, a small agricultural biotechnology company. In February 1996 there was a merger between the seed operations of Zeneca (formerly ICI, United Kingdom) and Suiker Unie, which owns the Vander Have Group from the Netherlands. The two corporations view the merger as an opportunity to mobilize the necessary critical mass for research, to benefit from the complementarity in their respective operations, and to increase the probability that the newly formed company will be one of a few large companies to dominate the market in the coming decades.

In March 1996, Sandoz and Ciba merged to form Novartis, which now is the second largest seed company in the world, with a turnover of $907 million in 1994. The former operations of Sandoz were estimated at $727 million and included four companies, Hilleshog NK (France), Northrup King (United States), S&G Seeds (the Netherlands), and Rogers (United States), with subsidiaries in twenty-five countries, and those of Ciba were in ten or more countries, with operations estimated at $180 million. Seed industry representatives expect such mergers to continue as companies attempt to build the minimum critical mass necessary for efficient R&D operations to be implemented and for products to be more competitive in the international marketplace.

In August 1997 DuPont announced a $1.7 billion investment in Pioneer Hi-Bred International. The alliance between the two companies represents a joint venture called "Optima Quality Products" which allows Pioneer to enhance the value of its germplasm, mainly maize, and provides DuPont with an effective delivery vehicle for marketing its broad range of output traits that confer enhanced nutritional value to food and feed products. In developing countries, where it is estimated that 80 percent of seed is currently supplied by government organizations or by farmer-saved seed, private sector activity in the seed industry is expected to become increasingly strong. Private sector growth is likely to be particularly important in Asia,(where most of the industrial country-based seed transnationals are active along with the Thailand-based CP Seed Company), as well as in Latin America and selected countries in Africa. As the former centrally planned economies of Eastern Europe and the Commonwealth of Independent States become politically and economically stable, these regions should also experience significant growth of the private sector seed industry.

Animal Health

The world market for animal health products was estimated to be $14.4 billion in 1995 (Wood Mackenzie 1997), as shown in Table 10. Animal health products are divided into four categories: nutritional feed additives; medicinal feed additives; biologicals; and pharmaceuticals. [These categories are defined in detail in the footnote of Table 10.] Pharmaceuticals represent just under half of the global market of animal health products, and nutritional feed additives approximately one-third. More than half of the total global pharmaceutical market of $6.4 billion is in the OECD countries, with sales of $2.1 billion in Europe, $1.9 billion in North America, $1.1 billion in East Asia, and $850 million in Latin America.

The data in Table 11 indicate that cattle account for 32 percent of the global market supply of animal health products (of which approximately half is pharmaceuticals) followed by pigs (23 percent), poultry (18 percent), and sheep (6 percent). In developed countries, care of domestic pets is a significant and growing market, making up approximately 20 percent of the global market in animal health products.

The animal health industry has many similarities to the crop protection industry in that the principal companies active internationally are either part of, or have association with, large transnationals that have operations in chemicals, pharmaceuticals, and biotechnology. Global sales of animal health products are dominated by the private sector. The top ten companies [see Table A-4], accounted for 60 percent of the world market of $14.4 billion in 1995. With the exception of the Tortuga Corporation (Brazil), all the principal companies are transnationals based in the United States (9), Europe (13), or

Table 10: Global Animal Health Sales in 1995, by Product Group and Region ($ millions)

Regions:	Nutritional Feed Additives	Medicinal Feed Additives	Bio-logicals	Pharma-ceuticals	Total
North America	1,042	675	530	1,858	4,105
Western Europe	1,092	492	645	2,066	4,295
East Asia (China, South-east Asia, Australia)	757	445	377	1,121	2,700
Eastern Europe	435	185	140	280	1,040
Latin America	294	198	358	850	1,700
Rest of World (Africa, Middle East, India)	170	95	90	175	530
World Total	**3,790**	**2,090**	**2,140**	**6,350**	**14,370**

Note. Product categories included the following: nutritional feed additives include vitamins, minerals, amino acids, non-protein nitrogen and other nutritionals; medicinal feed additives include antibiotics, antibacterials, anticoccidials, growth promotants, and other medicinals; biologicals include livestock biologicals, poultry biologicals, and companion animals; pharmaceuticals include antimicrobials, parasiticides, and performance enhancers.

Source: Wood Mackenzie (1997)

Table 11: Global Animal Health Sales by Product Group & Animal Species, 1995 ($ millions)

Animal Species	Nutritional Feed Additives	Medicinal Feed Additives	Biologicals	Pharma ceuticals	Total
Cattle	1,025	440	610	2,475	4,550
Pigs	1,100	730	285	1,120	3,235
Sheep	130	95	145	485	855
Poultry	1,065	765	500	240	2,570
Pets/Other	470	60	600	2,030	3,160
Total	**3,790**	**2,090**	**2,140**	**6,350**	**14,370**

Source: Wood Mackenzie (1997).

Japan (2), but they have significant and growing business in the developing countries estimated to be approximately 35 percent of the global market of $14.4 billion in 1995.

Biotechnology

Private sector investments in biotechnology are multidisciplinary in the sectors of medicine, pharmaceuticals, agriculture, and industrial applications such as fermentation. Because most private sector R&D investments are subject to a degree of confidentiality and many of the companies investing in biotechnology have multi-sector investments in biotechnology research, it is difficult to dis-aggregate the proportion of R&D investments devoted to agriculture. Thus, because there are no precise data available on biotechnology R&D expenditures, and because estimates are not always comparable due to lack of uniform methodology for consolidating and comparing data, the intent here is to describe the scope and scale of the investments and highlight order-of-magnitude differences.

Global R&D investments in 1990 by both public and private sectors in biotechnology for all sectors were estimated to be $11 billion, of which $6 billion was in the United States, $3 billion in Europe, and $2 billion in Japan; the private sector in Japan invested $1.4 billion (70 percent) of the total $2 billion (Persley 1990). Estimates of the relative contributions of the public and private sectors in the different biotechnology markets in 1985 (Persley 1990) are detailed in Tables 12, 13, and 14; they indicate that 50 percent of total global investments were in the USA, 25 percent in Europe, 15 percent in Japan and the balance of 10 percent in other countries. The estimates also show that global R&D expenditure in biotechnology by the private sector was $2.7 billion, slightly more than twice the $1.3 billion by the public sector. Corresponding comparisons for agricultural biotechnology indicate that slightly more than 60 percent of the investments were by the private sector and the balance by the public sector. Of the total $900 million spent in 1985 in agricultural biotechnology R&D by the public and private sectors, $550 million, equivalent to almost two-thirds of total expenditures, was spent by the private sector. Of the $900 million invested by both the public and private sector on agricultural biotechnology, two-thirds was spent on seed, and the balance on microbiology applications.

More recent data for 1995 on investments, revenues, and R&D expenditures show that there has been a dramatic increase in the decade 1985 to 1995. In the United States alone total sales of new biotechnology-based products in all sectors were almost $9.3 billion in 1995. It is estimated that sales will grow at 12 percent per year to reach $34 billion by the year 2006 (Ernst & Young 1995). More specifically, Table 15 shows that in 1995 sales of agricultural biotechnology products in the United States were approximately $100 million with an R&D expenditure of $2 billion; the corresponding sales for pharmaceutical products in 1995 were $7 billion sales and $8 billion in R&D. In 1996 the U.S. sales of agribiotech products increased to $304 million and this figure is expected to increase by 20 percent per year (Ernst & Young 1996). It is estimated that of the $10.8 billion total sales of biotechnology products in the United States in 1996, human therapeutics represented 75 percent of total sales, human diagnostics 17 percent, agriculture 3 percent, specialties 3 percent, and non-medical diagnostics 2 percent (Ernst & Young 1996, Persley 1997).

Table 12: 1985 Global Estimates of R&D Expenditures on Biotechnology, by Country or Region ($ millions)

Country or Region	Private sector	Public sector	Total
United States	1,500	600	2,100
European Union	700	300	1,000
Japan	400	200	600
Others	100	200	300
Total	**2,700**	**1,300**	**4,000**

Source: Persley, 1990.

Table 13: 1985 Global Estimates of R&D Expenditures on Biotechnology, Private and Public Sectors ($ millions)

Sector	Agricultural biotechnology	Other	Total
Private	550	2,150	2,700
Public	350	950	1,300
Total	**900**	**3,300**	**4,000**

Source: Persley, 1990.

Table 14: 1985 R&D Global Expenditures on Agricultural Biotechnology, by Application ($ millions)

Application	Private sector	Public sector	Total
Seeds	350	250	600
Microbiology	200	100	300
Total	**550**	**350**	**900**

Source: Persley, 1990.

Table 15: Sales and R&D Expenditures for Biotechnology Products in the United States, 1995 and 1996 ($ millions)

	1995	1996
Pharmaceutical Sales	7,000	8,600
Pharmaceutical R&D	8,000	N/A
Agricultural Sales	100	304
Agricultural R&D	2,000	N/A
Other Sales	2,200	1,896
Total Sales	**9,300**	**10,800**

Source: Compiled by Clive James and derived from Ernst & Young (1995), Ernst & Young (1996), & Wood Mackenzie (1997).

Whereas a high proportion of the R&D investments in agri-biotechnology are undertaken by the private sector, various public institutions and organizations that serve domestic and international interests are assigning higher priority to biotechnology. The World Bank has lent $100 million in support of biotechnology, whilst the Rockefeller Foundation and bilateral agencies, including those in the United States, U.K. and the Netherlands, have invested $200 million during the last decade (Brenner 1996). National research agencies such as USDA, BBSRC in the United Kingdom, and CSIRO in Australia, have also made significant investments in biotechnology. The CGIAR international agricultural research centers estimate that biotechnology expenditures are currently $22.4 million per year, of which $10 million is spent on animal biotechnology and the balance of approximately $12 billion on crop biotechnology by a total of eight centers (CGIAR 1996).

In terms of sales of agri-biotech products, it is estimated that transgenic seed comprise two-thirds to three-fourths of total sales of agri-biotech products. The People's Republic of China was the first country to commercialize transgenics in the early 1990s with the introduction of virus resistant tobacco, which was later followed by a virus resistant tomato. In 1994, Calgene obtained the first approval in the United States to commercialize a genetically modified food product, when the company marketed its Flavr Savr™ delayed ripening tomato. By 1996 approximately 7 million acres (2.8 million ha.) of seven principal transgenic crops (tobacco, cotton, soybean, corn, canola, tomato, and potato) were grown commercially on a significant area in the following six countries, listed in descending order of acreage: United States, China, Canada, Argentina, Australia, and Mexico. By trait, virus resistance accounted for 40 percent of the transgenic acreage in 1996, followed by insect resistance (37 percent), herbicide tolerance (23 percent), with quality traits accounting for less than 1 percent (James & Krattiger 1996). In 1997 the global area of transgenics increased significantly to 31.5 million acres (12.8 million ha.), with seven crops grown in six countries, as in 1996, with at least forty transgenic crops approved in at least one country (James 1997). Thus, the 1997 acreage of 31.5 million acres (8.1 million ha.) increased by a factor of 4.5 from the 7.0 million acres (2.8 million ha.) in 1996. The United States continued to be the principal grower of transgenic crops in 1997 and its share of global acreage increased from 51 percent in 1996 to 64 percent in 1997, equivalent to 20.1 million acres or 8.1 million hectares. The relative areas occupied by the four transgenic traits were also significantly different in 1996 and 1997. Herbicide tolerance, the third ranking trait in 1996, occupying 23 percent of the area, moved to the top ranking position in 1997 with 54 percent of the global area. Insect resistance was fairly stable with 37 percent in 1996 and 31 percent in 1997, with virus resistance decreasing sharply from 40 percent in 1996 to 14 percent in 1997; quality traits occupied less than 1 percent of total area in both 1996 and 1997. More comprehensive information on the benefits associated with new transgenic crops will be available following analysis of 1997 data, when the first substantial acreage of transgenics was planted globally, however initial results indicate that the benefits are significant (James 1997). Transgenic crops have been well received in North America, with a very high percentage of farmers planting transgenic crops in 1996, electing to plant again in 1997; many transgenic products were unavailable to potential growers in North America in 1997 because of shortage of transgenic seed supplies, and therefore reported acreages of transgenic crops are lower than the acreages planned by farmers.

There are numerous potential opportunities for applying biotechnology in developing countries, but for commercial reasons many of these will not be pursued by the private sector. These opportunities often exist for what are termed *orphan commodities* (Persley 1989; James and Persley 1991); for example, low-value, vegetatively propagated crops such as cassava and sweet potatoes, which are important primarily as staples for poor people in the developing world. Similarly, crops grown over a relatively small area would not be attractive to the private sector, even though these crops may make a vital contribution to the diet of poor people in a specific country or region. Given that basic biotechnology knowledge is broadly applicable to diverse problems, industry often has a comparative advantage in developing the most cost-effective solutions to many problems in the developing world. This situation represents a challenge to both developing countries and to international development agencies (James and Persley 1990), to develop effective biotechnology transfer programs to benefit subsistence farmers and orphan crops in developing countries.

Assuming equal research competence in the private and public sectors in the industrial countries, and acknowledging that industry's principal objective is product delivery, it is reasonable to suggest that the private sector will continue to be the principal, although not the only, generator of biotechnology products for agriculture. The comparative advantage of industry lies in several areas:

- Large R&D resources for funding long-term and sometimes high return, but speculative, agricultural projects.

- Diversity, from small, dedicated biotechnology companies to large transnational corporations that have extensive and increasingly collaborative research links with the public sector, particularly universities.
- Critical mass of scientific research resources, which is of paramount importance in biotechnology. These resources often are consolidated within a core research group in the private sector (e.g. in a life sciences department), which is a cost-effective way to provide common research support for two significant product development markets - medicine and agriculture.
- Knowledge of and expertise in marketing and distribution systems.
- Access to global markets and the associated advantages of economies of scale, which allow development costs to be amortized over long periods in large markets.

The advent of biotechnology has resulted in a significant change in the relative investments of the public and private sectors in agriculture, with the private sector now investing significantly more than the public sector in biotechnology R&D. As the adoption of biotechnology-based products in agriculture becomes more widespread, this gap between public and private sector investments is expected to be maintained or increase. This trend will be accentuated by current government policies, in both industrial and developing countries, that encourage participation by the private sector in areas where it has comparative advantages over the public sector. Estimates of future markets for agricultural biotechnology products vary; industry sources suggest that a realistic estimate is $3 billion to $5 billion for total sales at the farm level by the year 2000. Of this, seeds are predicted to comprise approximately $2 billion to $3 billion, with the balance in veterinary products and microbiology-based products. The increased market for agricultural biotechnology products is expected to be at the expense of existing markets, with some restructuring of those markets, rather than by major expansion of current markets (Persley, 1990). The global market for transgenic crops is projected to increase from $0.5 billion in 1996, to $2 to $3 billion in the year 2000, to $6 billion in 2005, and to $20 billion in 2010.

Summary of Private Sector Activities in Agricultural R & D

In summary, the private sector plays a major global role in agricultural R&D. The importance of its role is evident from the data presented in this section and in the appendix, even though these data do not include all the activities of the private sector; for example, the subsectors of post harvest/food processing and agricultural machinery, which are not featured, represent significant investments that are dominated by the private sector. In the future, private sector investments in agriculture and food are expected to increase faster than investments by the public sector, in both industrial and developing countries. Anderson *et al.* (1994) noted that, as farmers use more purchased inputs and as the value-added in agriculture increasingly moves off the farm to the marketing and processing subsectors, it is likely that the incentives for private sector investments in agricultural research will grow. With current private sector global revenues in fertilizers, seeds, pesticides and animal health alone estimated conservatively at approximately $80 billion per year, the private sector is an essential partner for the global public sector engaged in agricultural research.

The Need for Collaboration between the Public and Private Sectors

There is no greater incentive for collaboration between the public and private sectors in agricultural research than the enormous challenge posed by global food security, which will require that limited global resources be used in the most effective way to develop sustainable systems that also conserve natural resources. The urgency of this challenge cannot be overstated. Knowledgeable observers judge that the current joint investments of the public and private sectors in agricultural research are inadequate, to double (or preferably triple) agricultural production in the next fifty years. Furthermore, this is occurring at the same time external aid to agricultural research, which is viewed by many to be the catalyst that will stimulate economic growth in developing countries, and as the best antidote for poverty, is declining.

There is, and will continue to be, a critical and essential role for governments in developing countries to address policy issues in agriculture and to implement technical programs that optimize social welfare for the public good. Governments should not view for-profit private sector activities as detrimental to the public good because these private sector activities often are the most effective way – for example, in seed production and distribution - to achieve national goals set by governments. The collective goal must be to build partnerships that optimize the comparative advantages of the public and private sectors to achieve mutual goals. Governments have access to many policy instruments to encourage and stimulate private sector investments in joint venture programs, and donors can facilitate implementation of such collaborative programs (Anderson et al. 1994).

It is noteworthy that in the last decade there has been a strong trend for governments of donor countries to encourage, and in some cases require, increased participation by the private sector in agricultural research. Many of the more advanced developing countries have emulated this trend and established policies that encourage increased participation by the private sector in areas where it has comparative advantage. Whereas in the past policymakers in developing countries did not always recognize the private sector as an important resource for national programs, there has been a marked and progressive change in which the private sector is now generally acknowledged to be a key player in research and development. This view is endorsed by the international development and finance community, which recognizes the private sector in the North and the South as an increasingly important national and international resource (James and Persley 1990).

The significant investment of the private sector in biotechnology, perhaps more than any other single factor, has clearly demonstrated the need for and significant advantages associated with collaboration between the public and private sectors in agricultural research and development. Indeed the requirement for a minimum critical mass in R&D, particularly in biotechnology, has been the major stimulus for most of the mergers and acquisitions within the private sector. The development of biotechnology applications is capital intensive, requiring substantial long-term investments, which often can be mobilized only by the private sector. Thus, most investments in biotechnology are made by the private sector. A major challenge for both the private sector and the public sector is to find ways to collaborate in sharing and transferring appropriate new and superior technologies, which often are proprietary, from the private sector in the industrial countries to the public sector in the developing countries.

Collaboration between the public and private sectors is essential in planning future research strategies that are global in coverage, and requires cooperation by all the major entities in agricultural research in industrial and developing countries. This cooperation should ensure that limited global resources in agricultural research are used in the most effective way to strategically address the issue of food security in the developing world by optimizing the comparative advantages of the public and private sectors. Assuming that data from selected industrial and developing countries are representative, current private sector investments in agriculture and food R&D are conservatively estimated to be about $11 billion in the industrial countries and $2 billion in the developing countries; this compares with $8.5 and $8.8 billion, respectively, by the public sector. The issue here is not the precision of the estimates; rather, it is that both the public and private sectors are spending, independently, a total of approximately $30 billion on agricultural R&D. This $30 billion investment is inadequate to meet current global agricultural R&D needs. In addition, it does not benefit from the considerable efficiencies that could accrue if the same $30 billion were invested in a more coordinated manner by the public and private sectors. It is, therefore, vital that the two major players, the public and private sectors, involved in agricultural R&D on the global scene collaborate to address the important and impending challenge of global food security. Governments of developing countries, the donor community, and the private sector must take the necessary and urgent steps to initiate the building of partnerships. It is encouraging to note that there is cause for cautious optimism because several initiatives are already underway to build new partnerships between the public and private sectors. Three of these public-private initiatives are the founding of the International Service for the Acquisition of Biotech Applications (ISAAA) in 1991, the establishment of the Private Sector Committee of the CGIAR in 1995, and the formation of a Public-Private Sector Consortium by CAB International to support the development of a Global Electronic Crop Protection Compendium (CPC). These three initiatives, which are quite different in character, are described in the following pages.

Founding of The International Service for the Acquisition of Agri-biotech Applications (ISAAA)

The Mission

The mission of the International Service for the Acquisition of Agri-Biotech Applications is to help alleviate poverty by increasing crop productivity and income generation, particularly for resource-poor farmers, and to create a safer environment and promote a more sustainable agricultural development. ISAAA's objective is the transfer and delivery of appropriate biotechnology products, particularly proprietary technology from the private sector in the North, to developing countries in the South by building partnerships between institutions in the South and the private sector in the North.

The Need

In the past, developing countries, and the institutes which have assisted them with agricultural research, have had the privilege of freely accessing non-proprietary traditional technology from the public sector in the industrial countries. With the advent of new biotechnology applications, however, this situation is changing. The new applications are increasingly proprietary, and are owned primarily by private sector corporations in industrial countries, which account for the majority of the investment in biotechnology R&D on a global basis. The greatest need for agribiotechnology, however, is in the developing countries. The benefits of biotechnology generally are not accessible to developing countries due to institutional, political, and infrastructural constraints and to a lack of financial resources. The applications of agribiotechnology offer promising means to a more sustainable agriculture and a safer environment; for example, by providing alternatives to the use of toxic conventional pesticides. Conventional technology alone can no longer increase food, feed and fiber productivity at a growth rate fast enough to keep up with population growth and still respond to environmental and sustainability pressures. There is consensus in the scientific community that biotechnology is an essential element for increasing food, feed and fiber productivity in the future.

The Institutional Response

A new institutional mechanism, ISAAA, sponsored by public and private sector institutions, was created to transfer agri-biotech applications from industrial countries in the North, particularly proprietary technology from the private sector, to developing countries (James 1991, James and Krattiger 1993). ISAAA's role and comparative advantage as an honest broker is to bring together institutions from national programs in the South and from the private sector in the North, into partnerships to transfer biotechnology applications. Thus, ISAAA is not an executor but a facilitator. ISAAA's organizational structure permits both the public and private sectors to work together as true partners in an international biotechnology program for the benefit of the developing world. Acknowledging that technology adoption by resource poor farmers is, and probably always will be, challenging and difficult, emphasizes the importance of ISAAA's mission in its quest for equity in technology transfer. In the absence of organizations such as ISAAA, developing countries may be denied the opportunity to access the full potential that current and future superior biotechnology applications offer.

To assist developing countries in the acquisition and application of proprietary biotechnology applications, ISAAA was founded as a not-for-profit international organization. It is cosponsored by a troika of donor groups: philanthropic foundations, bilateral organizations and corporations from the private sector that provide financial support and share biotechnology applications. More than $13 million has been provided by a group of eighteen donors in support of ISAAA's program. ISAAA is a small, responsive, nonbureaucratic, international network. Two ISAAA Centers are already established in the North, the AmeriCenter at Cornell University in the United States and the *Euro*Center at the John Innes Centre, Norwich Research Park, United Kingdom. These two Northern Centers evaluate and monitor available technology applications and products for transfer to the South; links are maintained with Japan through a liaison group. The two Centers in the South are hosted by CGIAR centers which facilitates close cooperation with the international agricultural research centers (IARCs). The ISAAA *Afri*Center, established in 1994, is hosted by the International Potato Center on the ILRI campus in Nairobi, Kenya, and the ISAAA *SEAsia*Center is hosted by the International Rice Research Institute (IRRI) at its campus in Los Baños, the Philippines; plans to establish the *Lati*Center which will serve the needs of South America, are under consideration. Programmatic, organizational and policy guidance is provided by an International Board of Directors of prominent individuals representing developing and industrial countries, public and private sectors, and professional interest groups, including environmental protection.

ISAAA is funded by fixed-term commitments through a donor support group that includes a balanced representation of public and private sector institutions. No core funding is being mobilized, allowing full flexibility for changes in future directions without encumbering donors with long-term and less flexible core commitments. The fixed-term funding strategy exposes the program to regular peer review when accessing competitive international funding. Early tangible expressions of support from the public and private sectors were evident by the significant grants awarded to ISAAA by eighteen donors.

The Program

ISAAA has initiated a pilot program that uses a five step strategy to provide the following services:

- assist developing countries in identifying biotechnology needs and priorities and in assessing potential socioeconomic impacts, in a demand-driven program;
- monitor and evaluate the availability of appropriate biotechnology applications, particularly proprietary technologies from the private sector in industrialized countries;
- provide "honest broker" services, by matching needs with appropriate proprietary technologies;
- mobilize funding from donor agencies for client countries to implement projects;
- counsel developing countries on the safe and responsible testing of biotechnology products and provide targeted assistance for the implementation of biosafety and food safety regulatory procedures, socioeconomic analysis, the management of resistance genes, and intellectual property rights.

The Strategy

The strategy is to focus on the safe and effective introduction of near-term biotechnology applications that already have been tested in industrial countries, particularly to:

- emphasize applications to increase the productivity of food crops in the near-term, particularly *orphan commodities* grown by resource-poor farmers; contribute to sustainable agriculture and a safer environment through the development of alternative technologies to conventional toxic pesticides; and assign high priority to horticulture and forestry;
- concentrate on three classes of plant biotechnology applications: tissue culture, diagnostics, and transgenic crops; and
- assign priority to the assessment of benefits and constraints of biotechnology in developing countries, including biosafety and food safety considerations, and the responsible deployment of resistance genes to optimize durability.

ISAAA implements a demand-driven program that responds to the priority needs of twelve target national programs in Africa (Egypt, Kenya, and Zimbabwe), Asia (Indonesia, Malaysia, the Philippines, Thailand, and Vietnam) and Latin America (Argentina, Brazil, Costa Rica, and Mexico). These target countries were selected because they are developing nations that have some capability in agribiotechnology and the political will to play a leadership role in biotechnology transfer. Establishment of ISAAA centers in the South provides a physical location from where diffusion of technology to neighboring countries with similar needs can be achieved effectively at marginal cost.

Program Achievements

Approximately twelve ISAAA projects have been developed, brokered, and implemented or are under development. The most advanced model project involves Monsanto's donation in 1991 of coat protein genes to Mexico for the control of potato viruses (PVX/PVY); the project is funded by the Rockefeller Foundation and features technology transfer and training of Mexican scientists. The transgenic potatoes, developed by Mexican scientists, are currently being field-tested in Mexico and results are promising. Monsanto has also agreed to a South-South transfer of the PVX/PVY technology that will allow Mexico to share this technology with Kenya. A companion project assisted Mexico in developing the infrastructure and regulatory biosafety and food safety procedures for testing and introducing recombinant products. Discussions between Mexico and Monsanto in 1996/1997 led to another donation of a gene that confers resistance to the economically important potato leaf virus (PLRV); this technology transfer is aimed specifically at varieties, such as Rosita, that are grown exclusively by resource-poor farmers.

Other ISAAA projects include:

- Diagnostic for black rot of crucifers, one of the most important diseases of cabbage in Asia (Washington State University/Asian Vegetable Research and Development Center -AVRDC).
- Development and transfer of several diagnostics for maize diseases in Brazil (Pioneer Hi-Bred International/EMBRAPA).
- Diagnostic for Tomato Spotted Wilt Virus (TSWV) in horticultural crops in Indonesia and other countries in S.E. Asia (Novartis Seeds/Indonesia).

- Insect-resistant cotton (Monsanto/Brazil/Argentina).
- Transfer of a selectable marker gene in cassava (Sandoz/CIAT).
- Tissue culture-based pilot production facility for more productive, virus-free banana seedlings (South Africa/Costa Rica/Kenya/Uganda).
- Improved and healthier fruit trees with the application of diagnostics (Germany/South Africa/Zimbabwe).
- Breeding for maize streak virus resistance in maize (John Innes Center, United Kingdom/Kenya/Pan Africa).
- Micropropagation and distribution of multipurpose trees (Mondi Corporation, South Africa/Kenya).

Projects under development include:

- Transgenic sweet potatoes resistant to Feathery Mottle Virus, one of the most devastating virus diseases of sweet potatoes in Africa (Monsanto/Kenya/Rwanda/Tanzania/Uganda).
- S.E. Asia Network for the development and testing of transgenic papaya that is resistant to papaya Ring Spot Virus, and with a delayed ripening gene that reduces postharvest losses (ISAAA's target countries in S.E. Asia)

Project Support Activities

ISAAA initiated a series of activities to support project implementation. These include an initiative on biosafety, socioeconomic analysis, management of proprietary science and technologies, intellectual property rights, issues related to biodiversity, and deployment and management of crops resistant to insects (*Bt*). A series of five biosafety workshops were conducted in Argentina, Costa Rica, and Indonesia, and two in Kenya. An initiative to staff a full time position to provide support in the important area of proprietary science will be implemented early in 1998.

Investment in Human Capital, ISAAA's Fellowship Program

Recognizing that human capital and training are the most important factors for sustainable and successful projects, ISAAA has a strong fellowship program. Training, an element in all ISAAA projects, is essential to build capacity and sustainability vis-a-vis biotechnology in national programs and to preclude dependency of developing countries on industrial countries for the new technologies. To date, ISAAA has arranged mid-career training for thirty-five scientists from eleven countries in tissue-culture, transformation, regeneration, diagnostics and molecular biology. Unlike traditional training programs, which usually have involved the public sector in the industrial countries, a noteworthy feature of the ISAAA Fellowship Program is that most of the project-specific, hands-on training, has been undertaken with the private sector corporations, rather than with the public sector.

Four regional biosafety workshops organized in Latin America (2), Asia and Africa have provided training for almost 300 regulatory officials and scientists from developing countries in the promulgation and implementation of biosafety guidelines. In the workshops, representatives from the industrial country public sector regulatory agencies and from private sector corporations (which are the major users of biosafety regulations) have shared their experience with colleagues from the developing countries. The thrust of the biosafety activities is to build capacity in regulatory oversight in national programs. For projects that involve genetically engineered plants, ISAAA ensures that products are tested and introduced in a safe and effective way, and preferably in harmony with existing biosafety regulations in various industrial countries. A similar series of training activities will be initiated in 1998 to address the complex issues related to the management of proprietary science and technologies. Socioeconomic activities and studies are incorporated in all projects including those dealing with recombinant technology.

Summary

In summary, the ISAAA experience has already demonstrated that partnerships can be built between the public and private sectors to their mutual advantage, and that a series of win-win options can be negotiated. These options include a partnership between the public sector in a developing country and a private sector corporation in an industrial country that involves outright donation of a biotechnology application by the private sector corporation; a joint venture that involves a contribution of technology from the two partners (for example, adapted germplasm from the developing country and a gene that confers added value from the private sector corporation) with an arrangement for development costs and return on investments to be shared by both parties; and a partnership between two private sector corporations, one from the North and one from the South, to commercialize a product by optimizing the comparative advantages of the partners.

Establishment of the Private Sector Committee of the CGIAR

Proposal to Establish the Committee

At the CGIAR Ministerial-Level Meeting in Lucerne, Switzerland, 9—10 February 1995, ministers, heads of organizations and delegates representing the membership of the Consultative Group on International Agricultural Research (CGIAR) recommended that the CGIAR broaden its partnership within the global agricultural research system. More specifically, as part of their Declaration and Action Program statement, the Ministerial-Level meeting encouraged the CGIAR to convene a committee of the private sector as a means of improving the dialogue among the CGIAR, the private sector, and members of the civil society interested in the same issues as the CGIAR. Interaction between the committee and the CGIAR was envisioned to be collaborative and of a consultative nature. The CGIAR was urged to work in closer partnership and collaboration with the private sector in the North and in the South to design and conduct joint research programs, and to ensure that the CGIAR's research agenda reflects the views and goals of global and regional partners in agricultural research. Under the leadership of the Chairman of the CGIAR, Mr Ismail Serageldin, a proposal was developed, discussed, and agreed to by the CGIAR, to establish the committee which first met in December 1995.

Terms of Reference of the Committee

The Committee interacts with the CGIAR to provide a private sector perspective on the current status of global agricultural research and future needs. It serves as a link between the CGIAR and the agricultural private sector organizations at large, in the North and the South, and facilitates the liaison between the agricultural private sector and the CGIAR. Through rotation of membership, over time the committee will incorporate representative views of a broad cross section of the private sector in relation to policies, strategies, research priorities, and program activities in agricultural research and development in the North and in the South.

The CGIAR initiative to form the committee aims at encouraging the private sector to foster and develop new programmatic partnerships that exploit fully the respective strengths, network of relationships, and comparative advantages of the CGIAR and the private sector.

The Committee brings to the CGIAR its perspectives on issues such as the following:

- current and future needs and priorities for agricultural research and development in the developing countries;
- current and future strategies of the private sector, especially in the South, to respond to those needs;
- private sector views on CGIAR policies, strategies and activities, including views on recent private sector research breakthroughs or cutting-edge technologies that the private sector would be willing to share with the CGIAR;
- identification of program thrusts that represent an opportunity for the private sector and the CGIAR to collaborate and to optimize the comparative advantage of the respective partners to achieve mutual goals and objectives; and
- evolution of a new partnership between the private sector and the CGIAR that will represent a holistic and all-encompassing global approach to food security.

The Committee expects to carry out its work by:

- meeting two times per year, for approximately two days at locations in the North and in the South (these meetings may or may not coincide with the Mid-Term-Meeting and International Centers Week of the CGIAR);
- interacting with the various elements of the CGIAR system and the clients that it serves in the developing countries;
- consulting with the CGIAR and its Chairman, as necessary;
- organizing meetings, workshops and consultations to broaden interactions between CGIAR and private sector institutions; and
- presenting to the CGIAR views and proposals emerging from the committee's deliberations.

The Committee is represented at CGIAR meetings through attendance by the Co-Chairs.

Composition and Membership of the Committee

The Committee has ten private sector members, including two Co-Chairs, one from the North and one from the South. Half of the members are from the private sector in the North, the other half from the private sector in the South. Members were selected from small, medium and large companies and represent the major activities of the private sectors in the North and South focusing on the particular areas where the CGIAR is active, (for example, genetic improvement and management of crops, livestock, forest and fisheries; soil fertility; conservation and utilization of genetic resources; formulation of government food policies; and conservation and management of natural resources). The committee has reasonable geographic coverage and is a manageable size. Members are senior executives from the private sector who are leaders in their respective fields, have experience in strategic planning and policy decisions and have a broad range of professional backgrounds in the principal areas where the private sector and the CGIAR are active.

Initial Areas of Interest Identified by the Committee

The Committee has identified the following four topics for exploration and dialogue with the CGIAR:

- biotechnology—members are involved in the current Biotechnology Review in the CGIAR;
- intellectual property rights, genetic resources and biodiversity policy;
- mechanisms of interaction between the CGIAR, NARS and the private sector; and
- international centers and private sector practices in research and research management.

Summary

In summary, the establishment of the Private Sector Committee of the CGIAR represents an important development that should provide mutual benefits. The CGIAR, with a current annual budget of over $300 million (equivalent to 4 percent of public sector spending on agricultural research in the developing countries) is the single largest public sector investor in international agricultural R&D. The significant impact of the international centers of the CGIAR on productivity and production of staples, such as wheat and rice, is well documented and internationally recognized, evident by Dr. Norman Borlaug being awarded the Nobel Peace Prize in 1970 for his pioneering work on the semidwarf wheats. More recent objectives of the CGIAR focus on food self-reliance rather than food self-sufficiency, acknowledging that both agricultural and economic growth can alleviate poverty and the need for an eco-regional perspective to develop sustainable systems that conserve natural resources and protect the environment. The private sector faces the same challenges. These challenges demand more resources than the public and private sectors can marshal independently, and thus, it is both logical and desirable for the public and private sectors to collaborate in the pursuit of a goal that is vital for the future survival of the global community - food security.

Establishment by CAB International (CABI) of a Public-Private Sector Consortium to Support Development of the Global Electronic Compendium for Crop Protection (CPC)

It is estimated that crop pests (weeds, insects, diseases) reduce global crop production by up to 35 percent. Authoritative and current information on crop protection is a prerequisite for the development of knowledge-based pest management policies and strategies that optimize productivity and thus contribute to future world food security through the implementation of effective integrated pest management strategies. Workshops conducted by CABI in 1989 and 1992/1993 facilitated consultation with representative crop protection specialists from developing countries to determine the needs and priorities of national programs vis-a-vis crop protection. The lack of authoritative and current information, without which well-informed knowledge-based decisions are impossible, was determined to be an urgent priority need. Accordingly, workshop participants strongly endorsed the need for a Global Electronic Compendium for Crop Protection that would meet the needs of diverse users responsible for various aspects of crop protection globally.

In 1994 CABI conducted an extensive survey, focused on S.E. Asia, to determine the specific needs of different user groups in order to ensure that the Compendium would respond to needs and was demand-driven. The user survey determined strong demand for the Compendium from policy-makers responsible for crop protection in government and regional crop protection organizations, quarantine officers, researchers, extensionists, university teachers, agro-chemical industry personnel, and pest control managers implementing pest management schemes.

In early 1995 CABI made a decision to initiate the development of the Global Electronic Crop Protection Compendium in two modules (CABI 1996). Module 1 of the Global Compendium was developed during the first two years (1995 to 1997), starting with a focus on South East Asia and extended in the second two year period (1997 to 1999), with delivery of the Global Compendium scheduled for mid 1999. The development cost for the Compendium for the four year period 1995 to 1999 is $ 3 million, divided equally at $1.5 million for the first and second two year phases. Subject to successful resourcing of the development funds, CABI has made an up-front commitment to update the Compendium annually, using revenues from sales of the Compendium in industrial countries to update the product and offering preferential prices to developing countries to ensure affordability and equitable access to the product. CABI elected to form a public-private sector consortium to resource the compendium, thus facilitating broad participation by representatives of different user groups. Members derive significant benefits from the comparative advantages that CABI, as the developer of the compendium, offers the consortium. The following attributes characterize the compendium:

The Concept

The principal objective is to develop a knowledge-based multi-media electronic crop protection compendium that is global in scope; authoritative and current in content; capable of being operated in a user friendly mode, with a CD-ROM, or networked on a personal computer; and affordable to users in both the public and private sectors in developing and industrial countries. The Compendium provides a knowledge platform that allows users in developed and developing countries to easily access authoritative and current information on crop protection; the information can be readily applied to facilitate decisions in relation to all aspects of crop protection with a focus on integrated pest management. The Global Compendium will provide basic information on up to 20,000 pests/beneficial organisms, and detailed information on 2,000 insect pests, diseases, weeds and their natural enemies on 150 crops in 150 countries.

Content

The Compendium is a state-of-the-art information tool that will support knowledge-based decisions in crop protection and facilitate efficient international knowledge exchange in the following areas:

- ***integrated pest management*,** through comprehensive description of the full range of pest management practices in illustrated data sheets for the organisms of significance for crop protection, backed by a database of worldwide publications reflecting the experience of IPM in the field;
- ***crop protection and quarantine*,** through commodity-related lists of up to 20,000 pests, pathogens and weeds, plus electronically generated pest distribution maps which will optimize the cost effectiveness of pest risk analysis (PRA);
- ***biological control,*** through a facility to list and prioritize natural enemies for particular pests, their geographic distribution, and their use in IPM systems;
- ***pesticide usage data*,** classified by country, crop, and pest type for selected countries.

Module 1 of the Compendium, available as of mid 1997, has global relevance while focusing on the major pests of South-East Asia and the Pacific; it includes the following novel combination of features, on CD-ROM, updated annually, and can be migrated to the World Wide Web:

- ***pest data sheets*:** detailed data sheets for about 1,000 pests (including insects, diseases and weeds) and their natural enemies, written by 500 specialists. Focus on: identity, geographic distribution, biology, economic impact, control, with special attention paid to integrated pest management (IPM). Editing facilities to cut, paste, export, import and customize.
- ***crops and countries*:** data sheets on about 150 crops and 150 countries.
- ***basic data*:** names, distribution and host range for 12,000 pests and natural enemies.
- ***pictures*:** data sheets are linked to thousands of pictures of pests, natural enemies, crops or crop damage, usually in colour.
- ***maps:*** geographic data are automatically projected as distribution maps, global and regional, which can be overlaid with the distribution of a crop or natural enemy.
- ***relational database*:** factual data are stored in a multi-dimensional database, allowing retrieval of, for example, all fungi causing necrosis on the leaves of rice in China.
- ***hyperlinks*:** "soft" linking allows any word in any text to be used to seek related information, e.g. a country, a pest, a crop, a glossary definition, a reference.
- ***user notes*:** every data sheet has its own personal notepad, allowing in-context local storage of the user's personal experience of that item. Every data sheet has an optional second notepad, designed for corporate networking of shared information.
- ***diagnostic keys*:** a series of illustrated diagnostic keys to major groups of insects, and to nematode and weed species. Some are dichotomous; some (CABIKEYs) give multi-entry access, allowing the user to choose an approach to identification.
- ***taxonomic framework*:** every organism is placed in a taxonomic framework, which can be displayed and used for navigation.
- ***bibliographic references*:** 60,000 references, most with abstracts, either cited in the data sheets or important to IPM, including inaccessible "grey" literature

from several Asian countries. Powerful retrieval tool, offering natural-language searching.

- ***glossary*:** hyperlinked glossary of pest management terms; includes data on pesticide uses and environmental impact from the *Pesticide Manual*.
- ***production statistics*:** global crop production data, by country, including land use and pesticide trade statistics from FAO, with automatic charting facility.
- ***pesticide usage data*:** data for selected Asian countries from the *Landell Mills Database*.
- ***open architecture*:** modular structure allows links to be made to external information resources, such as additional bibliographic databases, and the World Wide Web.
- ***World Wide Web links*:** automatic launch of Web browser, with selected links from a Crop Protection Compendium Home Page (http://pest.cabweb.org/cpc/cpchp.htm).

Geographical Scope:
The scope is global coverage. Module 1 of the Global Compendium focuses on South East Asia, chosen because the crop protection problems of the region encompass those of other tropical and subtropical regions. The Global Compendium to be completed in mid 1999 will extend coverage to include up to 20,000 pests and natural enemies on 150 crops in 150 countries.

User groups:
A survey of user needs identified strong demand for the Compendium from extensionists, the agrochemical industry, quarantine officers, research scientists, university teachers, policy makers in government departments, and Regional Plant Protection Organizations.

Training:
The Electronic Compendium has a powerful and very important role to play in educational training at universities and other learning institutions. It also has an important role as a professional training tool for updating staff on new developments in crop protection in diverse organizations ranging from quarantine agencies, public sector institutions and private sector corporations, to organizations with responsibilities in crop protection.

Technological Considerations:
The Compendium uses original applications of the latest information technology (IT) to allow users friendly access to the most current and comprehensive data information and knowledge-base that will facilitate the development of solutions to practical problems in crop protection and pest management; thus the Compendium establishes a leadership role in the use of information technology for the benefit of all members of the global crop protection community.

Sustainability:
Subject to availability of funding from the Consortium for the development of the Global Compendium, CABI is committed to annual updating of the Compendium, revenue from sales in developed countries being used to offset annual updating costs.

CABI's Comparative Advantage:
As an international institution, CABI is dedicated to providing information that will contribute to more well informed, knowledge-based decisions; CABI can also greatly facilitate the effective exchange of information in the global crop protection community which will benefit both the consortium members and all the users of the Compendium. CABI's comparative advantage as the developer of the Compendium is related to many factors, including the following:

- its long experience in compiling and disseminating authoritative information in support of agriculture and forestry; it is the repository of the largest, most comprehensive, and extensive historical data base on agriculture in the world;
- its widely respected bibliographic database, CAB ABSTRACTS (comprising more than 3.5 million abstracts, of which more than 0.5 million relate to crop protection), specially enhanced through additional national contributions on IPM;
- its unique biosystematic expertise linked to practical application of biological control and IPM programs;
- its independent, inter-governmental status;
- construction of the Compendium is the responsibility of CABI which compiles information at regional and international levels, through coordinated input from the world's best-informed specialists who provide data of the quality required to be widely accepted as a reliable authority.

Affordability of the Compendium:
The purchase price of the Compendium is set so that it is affordable to the different user groups; there are differential prices for developed and developing countries, with reductions for bulk purchases and sponsorship.

The Compendium Consortium

The project to develop the *Crop Protection Compendium* is an initiative under the aegis of an International Development Consortium, organized by CABI, and currently comprises 22 members; 12 are from the public sector and 10 are from the private sector. As of October 1997, 22 members had already committed more than two-thirds of the total funding of $3 million required to complete the project; negotiations are currently underway with several potential new members to resource the balance of funding required. The 22 members of the Consortium are listed below in alphabetical order:

- Asian Development Bank (ADB)
- AgrEvo, Germany
- Australian Centre for International Agricultural Research (ACIAR), Australia
- CAB International,UK
- Canadian International Development Agency (CIDA)
- Cyanamid, USA
- Danish Government Institute of Seed Pathology / Danish International Development Agency (DGISP/DANIDA), Denmark
- DowElanco, USA
- DuPont, USA
- Gesellschaft für Technische Zusammenarbeit (GTZ), Germany
- International Development Research Center (IDRC), Canada
- International Rice Research Institute (IRRI), Philippines
- Monsanto, USA
- Novartis Crop Protection, Switzerland
- Overseas Development Administration (ODA; now DFID), UK
- Pioneer Hi-Bred International, USA
- Rohm & Haas, USA
- Sumitomo Chemical Company Limited, Japan
- Swiss Development Cooperation (SDC), Switzerland
- United Nations Development Program (UNDP)
- United States Department of Agriculture - Animal and Plant Health Inspection Service (USDA-APHIS)
- Zeneca Agrochemicals, UK

Consortium members can contribute to single or multiple units of membership and are offered privileges in recognition of their grant support, essential for the development of the Compendium. These include: membership in the Consortium which directs the future development of the Compendium; a complimentary copy of the Compendium, that can be networked and updated at no charge until the year 2002; and an option to purchase a specified number of copies at significant discounts to the published price in industrial countries.

Summary

In conclusion, in the context of this publication, it is appropriate to assess the benefits of the consortium approach, which represents a partnership facilitated by CABI, between public sector institutions and private sector corporations. The major benefit is that the Consortium approach allows a unique and state-of-the-art product to be developed to meet the common needs of different users in the most cost-effective way, using pooled resources from Consortium members. Whereas the monetary benefits are substantial, they are judged to be insignificant compared with the less tangible benefits that result from partnerships and cooperation *per se.* Simply stated, the Consortium members, collectively, have benefited from an authoritative product, funded through affordable contributions, that no single member of the Consortium could possibly have developed on their own. As a consequence of cooperation during the development of the Compendium, Consortium members can also greatly facilitate the adoption of the CPC as an internationally recognized knowledge-base, to facilitate improved and well informed decisions vis-a-vis crop protection. For example, different views on quarantine issues often arise because agencies have access to inadequate or incomplete information. The advent of a knowledge-base that has benefited from the inputs and experience of diverse organizations involved in all the different aspects of crop protection, and where data is validated and updated annually, is judged to be an important development; this is particularly important when globalization of agricultural trade is underway and where constraints associated with non-tariff trade barriers are becoming increasingly important. Finally, the concept that the Compendium is "owned" by Consortium members provides the incentive and motivation for active participation and the full exploitation of the comparative advantages of respective members for their collective and mutual benefit. In this context, the Electronic Note Pad, featured in the Compendium, provides an opportunity for all Compendium users (not only Consortium members) to share information on any aspect of crop protection with CABI, which in turn can utilize it to update the Compendium. Thus, participation in the future development of the Compendium can be broadened, through the use of the Electronic Note Pad, to include all users in a global network that can effectively exchange information and better serve the needs of the global crop protection community. The Compendium has the potential to allow crop protection specialists in developing countries to benefit from novel, state-of-the-art IT technology that will enable them to be equitable participants in a global network, and share information that in the past resided in gray literature, or was never documented; for example, information on crop protection practices in subsistence farming in developing countries. Similarly, the Compendium provides an excellent vehicle for the countries of the South to exchange information and harmonize understanding with the North, and likewise between the public and the private sector. In the 21st century, one of the challenges will be to forge new partnerships so that use of limited resources can be optimized. Experience with the development of the Crop Protection Compendium indicates that opportunities to further explore are the establishment of consortia, where common needs can be met with the collective action of members whose respective comparative advantages and diverse viewpoints can be mobilized cost-effectively to meet mutual goals and objectives.

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Table A-1: **Principal Fertilizer Companies ***
(Listed alphabetically for Nitrogen, Phosphate & Potash producers)

Company	Country
Nitrogen/Ammonia (N)	
Arcadian	USA
CF Industries	USA
DSM Agro BV	Netherlands
Farmland Industries Inc.	USA
ICI Fertilizer	UK
Kemira Oy	Finland
National Fertilizer Ltd.	India
Norak Hydro As.	Norway
Pemex	Mexico
Pupuk Kaltim	Indonesia
Rashtriya Chemicals & Fertilizers Ltd.	India
Phosphate (P_2O_5)	
CF Industries	USA
Freeport McMoran Resource Partners	USA
ICW/SIAPE/SAEPA	Tunisia
IMC Fertilizer Group Inc.	USA
Occidental Chemical Corp. Ag.Products	USA
OCP	Morocco
Texas Gulf Inc.	USA
Potash (K_2O)	
Arab Potash Company	Jordan
Entreprise Miniére et Chimique	France
Dead Sea Works	Israel
IMC Fertilizer Group Inc.	USA
Kali and Salz	Germany
Kallum Chemicals	Canada
Potash Corporation of Saskatchewan	Canada

* List excludes producers in China, Former Soviet Union, and Central Europe
Source: Communication from International Fertilizer Industry Association (IFIA), Paris, France.

Table A-2: **Major Plant Protection Companies** (Based On Estimated 1996 Global Sales of Crop Protection Products)

Rank	Name	Country	Approx. Sales (US$ Million)
1	Novartis	Switzerland	4,175
2	Monsanto	USA	2,872
3	Zeneca	UK	2,849
4	DuPont	USA	2,515
5	AgrEvo	Germany	2,451
6	Bayer	Germany	2,305
7	Rhône-Poulenc	France	2,174
8	DowElanco	USA	2,005
9	Cyanamid	USA	1,989
10	BASF	Germany	1,506
11	Sumitomo	Japan	648
12	FMC	USA	595
13	Rohm & Haas	USA	514
14	Ishihara	Japan	495
15	Makhetshim-Agan	Israel	472
16	Kumiai	Japan	464
17	Nihon Nohyaku	Japan	376
18	Sankyo	Japan	371
19	Uniroyal	USA	353
20	Hokko	Japan	330
21	Takeda	Japan	321
22	Nissan	Japan	320
23	Nufarm (Fernz)	New Zealand	317
24	Atochem	France	265
25	Nippon Soda	Japan	264
Total (US$ Million)			**30,946**

Source: Wood Mackenzie (1997).

Table A-3: **Major International Seed Companies** (Ranked by Worldwide Sales 1996)

			Approx. Sales	Crops								Marketing Regions				
Rank	**Name**	**Country**	(Million US $)	Cereals	Maize	Oilseed	Forage	Sugar-beet	Protein Crops	Flower & Vegs.	Cotton /Rice	North America	Europe	South America	Asia	Africa
1	Pioneer	USA	1,600	X	X	X	X					X	X	X	X	X
2	Novartis	Switzerland	970		X	X	X	X	X	X		X	X	X	X	X
3	Limagrain	France	660	X	X	X	X	X	X	X		X	X	X	X	X
4	Monsanto	USA	600	X	X	X			X		X	X	X	X	X	
5	Advanta	Netherlands /U.K.	470	X	X	X	X	X	X	X		X	X	X	X	X
6	Takii	Japan	450				X			X		X	X		X	
7	Dekalb Plant Genetics	USA	387		X	X	X					X	X	X	X	X
8	Seminis	Mexico	380		X	X	X		X	X		X	X	X		X
9	Sakata	Japan	360							X					X	
10	KWS	Germany	350	X	X	X	X	X	X	X		X	X	X	X	
11	Cargill	USA	250	X	X	X				X	X	X	X	X	X	
12	Cebeco	Netherlands	170	X	X	X	X		X	X		X	X			
13	Pau Euralis	France	162	X	X	X						X	X			
14	Svalof Welbull	Sweden	160	X	X	X	X		X	X		X	X	X		
15	RAGT	France	150	X	X	X	X						X			
16	Mycogen (Dow Elanco)	USA	147	X	X	X	X					X	X	X		
17	Saaten-Union	Germany	140	X	X	X	X	X	X				X			
18	Sigma Semences de France	France	135	X	X	X	X	X	X				X			
19	DLF Trifollum	Denmark	130			X	X	X	X			X	X		X	
20	Barenbrug	Netherlands	125	X	X	X	X		X			X	X	X	X	
Total	(US$ Millions)		**7,796**													

Source: Calliez (1997).

Table A-4: Major Animal Health Companies
(Based on Estimated 1995 Global Sales of Animal Health & Nutrition Products)

Rank	Name	Country	Sales (US$ Million)
1	Hoffman-La Roche	Switzerland	1,440
2	Rhône-Poulenc	France	1,357
3	Pfizer	USA	1,250
4	Merck	USA	792
5	Bayer	Germany	754
6	Novartis	Switzerland	743
7	BASF	Germany	738
8=	Hoechst	Germany	512
8=	Eli Lilly	USA	512
10	Mallinckrodt	USA	454
11	American Home Products	USA	389
12	Pharmacia & Upjohn	USA	383
13	Degussa	Germany	355
14	Akzo Intervet	Netherlands	272
15	Solvay	Belgium	265
16	Virbac	France	243
17	Novus	USA	238
18	Boehringer Ingelheim	Germany	222
19	Sanofi	France	202
20	Schering-Plough	USA	190
21	Alpharma	USA	163
22	Takeda	Japan	157
23	Janssen	Belgium	145
24	Nippon Zenyaku	Japan	144
25	Tortuga	Brazil	134
Total	(US$ Million)		**12,054**

Source: Wood Mackenzie (1997).

US$ 10.00