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Measuring Agricultural Biotechnology Research Capacity In Four Developing Countries

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In 1998, the International Service for National Agricultural Research (ISNAR) conducted a biotechnology research indicator survey of four national agricultural research systems—in Mexico, Kenya, Indonesia, and Zimbabwe. Some of the policy recommendations proposed to overcome the identified limitations in conducting biotechnology research include: an increase of investment levels in agricultural biotechnology, the promotion of the private sector's involvement, and the development of a comprehensive strategy.

Key words*: research indicators; biotechnology; developing countries.*

Information on the size, structure, and content of public research is generally needed to improve policy decisions, clarify the roles of the public and private sectors, and support public sector research implementation. Currently, there is a lack of structured data on resources for agricultural biotechnology in developing countries. This paper provides information on the development of agricultural biotechnology research in four developing countries: Mexico, Kenya, Indonesia and Zimbabwe.

The information provided here was obtained through a survey of the most relevant public and private organizations involved in agricultural biotechnology research in these four countries. The sample represents 70-80% of total expenditures on agricultural biotechnology research in each country. Out of 34 organizations surveyed, thirteen were public research institutes, eleven were public universities, six were private non-commercial organizations, and four were private commercial entities.

Institutional Capacity And Policy Development

Mexico

Mexico established its first tissue culture laboratory in 1970. The national biotechnology research units were established in the early 1980s. They include the Biotechnology Institute at the Autonomous National University of Mexico, the Center for Research and Advanced Studies—

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Irapuato Unit (CINVESTAV), and the Scientific Research Center of Yucatan. Because these research centers apply advanced biotechnology techniques, Mexico has a leading position among developing countries. From a regulatory perspective, plant breeders' rights (PBR), and industrial property are recognized. A Biosafety Committee was established in 1989.

Even without a biotechnology policy, Mexico has made progress in biotechnology. It is close to generating the first transgenic product to be released by a national organization in Latin America (CINVESTAV, in collaboration with Monsanto).

Indonesia

In 1985, Indonesia established the Inter-University Center for agricultural biotechnology to train university faculty, and the Research and Development Center for Biotechnology (RDCB) to enhance national biotechnology capacity. The Biotechnology Division of the Central Research Institute for Food Crops (CRIFC) was established slightly later in 1989. In 1995, the Research Institute for Food Crops Biotechnology (RIFCB) was created after merging the CRIFC and Bogor Research Institute for Food Crops. The Research Institute for Food Crops Biotechnology and RDCB apply advanced techniques, and are leaders in agricultural biotechnology. Biosafety regulations and the Biosafety Commission were both established in 1997. A patent law from 1989 was revised in 1997 to protect biotechnology products. However, plant breeding rights are not in place.

Zimbabwe and Kenya

Zimbabwe and Kenya have developed similar biotechnology research capacities. Kenya Agricultural Research Institute (KARI) started using biotechnology in 1982. Zimbabwe's Biotechnology Research Institute (BRI) was established later in 1992. The emphasis on biotechnology started in 1992, with the Special Program Biotechnology, supported by the Netherlands. Kenya's Agricultural Biotechnology Platform and Zimbabwe's Biotechnology Advisory Committee were established in 1996. They advise governments and Dutch-supported special programs on developing agricultural biotechnology.

Kenya's Biosafety Committee was appointed in 1996. The Industrial Property Act was implemented in 1993, and the Plant Varieties Act followed in 1994. In Zimbabwe, biosafety regulations were established in 1998, and the National Biosafety Committee was formed in 1999. An existing industrial patent law and plant breeding rights (from the 1970s) still need to be adapted to biotechnology.

While creating biosafety committees and revising property rights legislation favors private sector participation, such actions remain limited in agricultural biotechnology research. Few private companies are engaged in advanced biotechnology research; most specialize in the application of tissue culture techniques to fruits and ornamentals.

Research Expenditures

Tables 1 and 2 present an overview of research expenditures, which have shown a positive, but variable, growth. Agricultural biotechnology research is done mainly by the public sector, accounting for 92% of expenditures. The private sector accounts for 8%, on average, but it has had higher annual growth than public universities (except in Indonesia). Universities showed a significant decline in expenditures, probably due to economic recession and the cyclical nature of donor funding.

Table 1. Expenditures On Agricultural Biotechnology Research By Mexico & Kenya.

	Mexico			Kenya		
	1985	**1997**	**Annual Growth (%)**	**1989**	**1996**	**Annual Growth (%)**
Total Expenditures (millions 1985 PPP dollars [a])	9.7	20.4	6.3	2.5	3.0	2.6
Percentage of Total Expenditures						
Public Research Institutes	50	60	8.9	47	72	8.9
Public Universities	50	28	0.5	49	24	-7.3
Private Non-Commercial	0	4	22.5	4	4	3.3
Private Commercial	0	8	40.9	0	0	0.0
Expenditures Per Researcher (thousands 1985 PPP dollars [a])	187.5	85.1	-6.4	77.2	45.5	-7.2
Total Expenditures (percentage of total agricultural research)	3.1	9.6	9.8	3.3	2.8	-2.3

[a] Research expenditures are presented in real international dollars converted by the purchasing power parity (PPP) index. From "Agricultural Biotechnology Research Indicators and Managerial Considerations in Four Developing Countries," by C. Falconi, 1999, in Managing Agricultural Biotechnology, Addressing Research Program Needs and Policy Implications, J. Cohen (ed.). The Netherlands: ISNAR-CABI.

Public institutes showed the highest share of financial resources and the highest annual growth, due to the concentration of financial resources in a few public institutes. The Kenya Agricultural Research Institute had 70% of Kenya's total expenditures in 1996, BRI had 80% of Zimbabwe's expenditures in 1998, three organizations had 70% of Indonesia's expenditures in 1997, and three organizations had 55% of Mexico's in 1997. These expenditures contrast sharply with those of developed countries. In 1992, the private commercial sector financed 70% of agricultural biotechnology research expenditures in the United States (Fuglie *et al*., 1996).

The number of researchers engaged in agricultural biotechnology research has outpaced research expenditures in Kenya, Mexico, and Zimbabwe. Hence, a decline in expenditures per researcher of 7% annually has occurred. Only two private Mexican commercial entities showed positive expenditure growth, and higher overall levels of expenditure per researcher than the public sector. Similarly, Indonesia showed significant annual growth in expenditures per researcher, however, these declined sharply in 1997 due to the Asian financial crisis.

Agricultural biotechnology research expenditures, as a percentage of total agricultural research expenditures, were 2.3% for Kenya, 6.5% for Mexico, 7.0% for Indonesia, and 5.0% for Zimbabwe. In comparison, the Consultative Group on International Agricultural Research (CGIAR) spent 8% of its 1997 budget on biotechnology research, and the United States allocated 13% of its 1992 agricultural research expenditures to biotechnology.

Table 2. Expenditures On Agricultural Biotechnology Research By Indonesia & Zimbabwe.

	Indonesia[a]			Zimbabwe		
	1989	1997	Annual Growth (%)	1989	1998	Annual Growth (%)
Total Expenditures (millions 1985 PPP dollars[b])	2.4	18.7	29.3	1.8	3.5	7.5
Percentage of Total Expenditures						
Public Research Institutes	66	85	33.4	2	81	69.3
Public Universities	14	11	25.7	98	3	-26.8
Private Non-Commercial	0	1	9.8	0	16	11.5[c]
Private Commercial	20	3	1.3	0	0	0.0
Expenditures Per Researcher (thousands 1985 PPP dollars[b])	19.1	53.6	13.7	92	43	-8.0
Total Expenditures (percentage of total agricultural research)	1.7	9.6	24.1	4.6	10.0	9.0

[a] Total agricultural research expenditures only include the Agency for Agricultural Research and Development. [b] Research expenditures are presented in real international dollars converted by the purchasing power parity (PPP) index. [c] The annual growth rate is from 1992 to 1998. From From "Agricultural Biotechnology Research Indicators and Managerial Considerations in Four Developing Countries," by C. Falconi, 1999, in Managing Agricultural Biotechnology, Addressing Research Program Needs and Policy Implications, J. Cohen (ed.). The Netherlands: ISNAR-CABI.

Financing

Donor share of total agricultural biotechnology expenditures (table 3) has been considerable in Kenya (67%) and Zimbabwe (50%). Without an effort to acquire funding locally, these levels will be compromised in the medium term. In Mexico and Indonesia, on the other hand, government contributions represent about 60% and 93%, respectively, of total expenditures on agricultural biotechnology. Some

public institutes and universities fund their research activities from non-traditional sources, for example, from sales of products and services and contractual arrangements, indicating a marginal relationship with the private sector. These sources provide minimal funding, but they did increase during the period of analysis. Private non-commercial organizations are funded by contracts or levies, while private commercial organizations are financed by the sales of their products.

Table 3. Agricultural Biotechnology Sources Of Funding.

Source of Funding	Kenya (1996) (%)	Mexico (1997) (%)	Indonesia (1997) (%)	Zimbabwe (1998) (%)
Government	28	60	93	34
Sales of Products	3	12	4	16
Contracts	0	4	1	0
Donors	67	24	2	50
Levies	2	0	0	0
Total	**100**	**100**	**100**	**100**

From "Agricultural Biotechnology Research Indicators and Managerial Considerations in Four Developing Countries," by C. Falconi, 1999, in Managing Agricultural Biotechnology, Addressing Research Program Needs and Policy Implications, J. Cohen (ed.). The Netherlands: ISNAR-CABI.

Personnel

In terms of personnel changes, the total number of researchers has at least doubled in all four countries, with those holding a Ph.D. degree increasing by at least three times (table 4). This is due to a significant increase in the number of postgraduate programs in biotechnology, specialized research organizations that require scientists trained in biotechnology, and special grant programs that encourage involvement in biotechnology.

Personnel are concentrated in a few public organizations: 45% of Kenyan researchers are located in KARI, 60% of Mexican researchers are located in just four research organizations, 60% of Indonesians are located in three organizations, and 70% of Zimbabweans are located in three organizations.

Downer *et al*. (1990) recommend a ratio of two support personnel (technicians) per researcher for genetic engineering and tissue culture. In the surveyed countries, the average ratio is 1:2, a low ratio that could affect research outputs. Only three private commercial entities, with an average ratio of 5:1, had a ratio greater than 1:1.

Research Focus

The main research focus of researchers in biotechnology was crops, with around 85% of researchers working in this area; the remaining researchers worked on livestock. This share does not match the contribution of livestock to agricultural production value (35% on average).

The distribution of researchers on the gradient of biotechnology techniques is a good indicator of biotechnology development. In Mexico and Indonesia, half of researchers utilize advanced techniques, including genetic engineering. The other half uses less-sophisticated techniques, such as tissue culture. In Kenya and Zimbabwe, 70% of researchers use less-sophisticated techniques, while 30% use advanced techniques.

Table 4. Agricultural Biotechnology Research Personnel.

	Mexico		Kenya		Indonesia		Zimbabwe	
Researchers[a]	**1985**	**1997**	**1989**	**1996**	**1989**	**1997**	**1989**	**1998**
PhD	14	127	14	41	50	102	5	27
MS	12	49	12	15	28	93	5	31
BSc	25	62	6	9	47	154	9	23
Total	**51**	**238**	**31**	**64**	**125**	**349**	**19**	**81**
Researchers per Technical Support	3.1	2.1	2.0	1.4	1.3	1.4	1.1	2.1

[a] On leave researchers are not included. From "Agricultural Biotechnology Research Indicators and Managerial Considerations in Four Developing Countries," by C. Falconi, 1999, in Managing Agricultural Biotechnology, Addressing Research Program Needs and Policy Implications, J. Cohen (ed.). The Netherlands: ISNAR-CABI.

Private-sector organizations use mainly less-advanced techniques such as tissue culture (around 80% of private researchers). Less-advanced techniques are less costly, less risky, and closer to the market. The more advanced techniques, such as genetic engineering which are more expensive and the payoffs more uncertain, are used mainly by public-sector organizations (around 40% of public researchers). However, a significant proportion of public researchers is using less-advanced techniques. This can be explained by the continuum of biotechnology (advanced techniques are complemented by less-advanced techniques), the emphasis of the public-sector also applies biotechnology to "orphan" commodities and to solving problems facing marginal farmers. This sectoral "division of labor" should be taken into account by research leaders and decision-makers. Partnership between the private and public sectors should be promoted.

Findings And Policy Recommendations

A number of findings from the survey are as follows:

- Most organizations are still in the first stages of developing biotechnology research capacity, though there has been an increase in capacity – especially in terms of human capital.

- The proportion of biotechnology expenditures to total agricultural research expenditures is still small.

- There is a significant decline in operating expenditures per researcher, as operative expenditures have followed increases in personnel. This trend could lead to unsustainability or low performance.

- Funding and execution of biotechnology research is highly dependent on the public sector, and private sector participation is limited.

- Donor contributions constituted the largest source of funding for agricultural biotechnology research in Kenya and Zimbabwe, raising concerns over the maintenance or expansion of agricultural biotechnology.

- Most agricultural biotechnology research is focused on crops, with a limited emphasis on livestock.

- The private sector focuses on the near-market and low-technology end of biotechnology, and on horticultural crops, such as ornamentals and fruits.

- A comprehensive national strategy is generally lacking.

These findings lead to the following policy recommendations:

- Planning and priority-setting are needed for the development of a strategy that fosters biotechnology.

- There is a need for more national and institutional commitment to fund agricultural biotechnology research.

- The issue of sustainability and user-orientation needs to be addressed.

- Policies and incentive mechanisms should be developed to encourage private-sector investment and public-and-private sector research partnership.

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