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SUSTAINABLE AGRICULTURAL DEVELOPMENT: THE ROLE OF INTERNATIONAL COOPERATION

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Edited by
G.H. Peters, Agricultural Economics Unit, Queen Elizabeth House,
University of Oxford, England
and
B.F. Stanton, Cornell University, USA
Assisted by
G.J. Tyler
University of Oxford

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QUEEN ELIZABETH HOUSE
UNIVERSITY OF OXFORD

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*Biotechnology and the International
Agriculture Research Centres of the CGIAR*

INTRODUCTION

The euphoria of the 'green revolution', which was at once the first-born and the father of the Consultative Group on International Agricultural Research (CGIAR), is on the wane. Herdt and others have drawn attention to the fact that existing yield potential in rice, the basic food staple for the majority of the world's poor, is already being achieved by farmers in areas where population pressures are greatest. There is no more slack (Herdt, 1988; De Datta *et al.*, 1988). W. David Hopper, recently retired Chairman of the CGIAR, has commented:

Unless there is a significant advance in productivity, far greater than I see evident from the present data from the CGIAR centres and others engaged in tropical agricultural research, I do not see us being able to beat the Malthusian proposition by 2000 or 2030....the next significant advances must come from genetic engineering. (Hopper, 1990)

The CGIAR system will be one set of institutions helping to disseminate the benefits of biotechnology.

THE CGIAR IN PERSPECTIVE

The CGIAR perceives itself as an international component in a global agricultural research system. One role is to link scientific capacity in the developed and developing worlds for the benefit of small Third World farmers and poor consumers. Historically, the reputation of the CGIAR system has rested on the development and transfer of improved germ-plasm, particularly the short-strawed rices and wheats which contributed to the 'green revolution'. Improved germ-plasm of other crops from the newer International Agricultural Research Centres (IARCs) is increasingly moving into farmers' fields. This germ-plasm improvement is paralleled by world-wide efforts to conserve crop genetic resources and to improve the management and productivity of both crops and animals in small farming systems.

*Consultative Group on International Agricultural Research, Washington, USA.

Global and regional research remains ivory-towered, unless effectively mobilized by Third World national agricultural research and development systems. A vital goal for the CGIAR is the build-up of national agricultural research institutions to meet the needs of their small farmer clients with new technologies. Some 20 per cent of the annual CGIAR budget is spent on training, institution building and food policy analysis towards this goal.

After the current expansion from the 13 to 18 IARCs is complete, the expected budget of approximately US\$320 m. a year for the CGIAR will still represent significantly less than 10 per cent of total annual investment in developing country agricultural research and less than 0.7 per cent of official development assistance. The CGIAR annual budget is just over 50 per cent of the US\$612 m. R&D budget of Monsanto, a major agricultural chemical company ranked twenty-fourth for corporate R&D spending in the USA. As another comparator, the number of scientists employed in agricultural research in developing countries, excluding the Peoples Republic of China, was estimated to be over 45 000 for the period 1980–5 (Pardey and Roseboom, 1988). The CGIAR employs some 1 700 scientists with MSc qualification or higher.

In the USA, a dual pattern has emerged in the private sector. On the one hand, large agricultural chemical and seed companies such as Monsanto have moved into biotechnology to exploit complementarities in their product range. Monsanto has 240 senior scientists working in animal and plant biotechnology with an annual expenditure of about US\$55m., approximately 9 per cent of the company's total R&D budget (Fraley, personal communication, March 1991). On the other hand, small venture capital companies have also emerged. One such company is Calgene of Davis, California. In 1989, Calgene had an annual R&D budget of US\$10.5m. supporting 50 research scientists, equal to one-half of the value of the company's product sales for the year (Calgene, spokesperson, personal communication, March 1991).

The 1990 CGIAR budget included approximately US\$14.5m. for biotechnology, about 4.5 per cent of the budget for the system as a whole. Half of this was for plant biotechnology, distributed across nine crop-improvement centres working on some 15 crops. The other half went to animal biotechnology, primarily at ILRAD, a centre working on animal diseases and focused exclusively on state-of-the-art molecular biology. While ILRAD expenditures have grown slowly over the years, the budget for plant biotechnology in the CGIAR centres has increased to US\$7.5m from US\$4.3m. over the last two years. Currently, across the CGIAR system, some 65 senior scientists, including post-doctoral fellows, work on biotechnology – half of these in the plant sciences.

BIOTECHNOLOGY IN THE CGIAR

The diverse range of biotechnology research activities found in the IARCs is indicative of the wide scope of the available techniques. Current research includes plant tissue and cell culture (anther culture, somaclonal variation, meristem culture, rapid clonal propagation), *in vitro* germ-plasm conservation,

molecular diagnostics (nucleic acid probes, monoclonal antibodies, enzyme-linked immunosorbant assay (ELISA)), embryo rescue and genetic engineering (Plucknett, Cohen and Horne, 1990).

The CGIAR crop improvement centres have been cautious, some would say over-cautious, in embracing biotechnology. The CGIAR first addressed issues in biotechnology at the Inter-Centre Seminar on 'The IARCs and Biotechnology', hosted by IRRI in 1984. The following year a paper was presented at a joint CGIAR/Japanese forum on biotechnology (Plucknett, 1985). The Technical Advisory Committee (TAC) – a group of eminent scientists which guide the scientific programme of the CGIAR – also approached biotechnology cautiously. In 1988, the Committee issued the first policy statement on biotechnology in the CGIAR. Most recently, a joint statement by the CGIAR Centre Directors at the Mid-Term CGIAR Meeting, in May 1990 noted:

It is for each centre to determine the role that biotechnology can play in solving the problems that it confronts in fulfilling its mandate, to assess its fitness to apply biotechnological solutions, and its comparative advantage as a player within the CGIAR system and the scientific research community as a whole. (CGIAR, 1990)

CGIAR biotechnology strategy

Genetic engineering of crops requires a sophisticated research effort. Private companies are particularly adroit at organizing the complex and expensive teams needed. For example, the successful engineering of *Bacillus thuringiensis* endotoxin genes in several companies appears to have involved 5–10 full-time scientists working directly on each effort for several years to develop resistant plant materials worth taking to the field. At \$100 000 per scientist per year, this represents an investment of the order of \$1.5–3m. to get one gene transferred into one crop – a significant investment (Mueesen, 1990). Such modern biotechnological research in plant science provides intermediate products, rarely useful in isolation and dependent on the traditional routines of plant breeding to bring the improved product to farmers.

'Understanding of the biology of plants at the molecular level needs to be dovetailed with understanding of the plants at the tissue, whole plant and population levels, and finally reconciled with the socio-economic circumstances of producers' (Javier, 1990).

The strategy of the IARCs embraces this perspective of biotechnology as the tip of the R&D iceberg in agriculture. A balance between biotechnology and conventional research is crucial to the CGIAR role in the sustainable improvement of agricultural productivity in developing countries. Thus the strategy of the CGIAR crop improvement centres is to use relevant, tested, biotechnology techniques for more efficient resolution of their existing research agendas.

The well established linkage strategy of the IARCs, coopting and passing on useful research techniques to National Agricultural Research Systems (NARS), will also be a way forward in biotechnology, particularly for smaller

NARS. One route may be to link the IARCs with LDC universities as future centres of strategic research. As skills mature, the universities can then exploit IARC connections to begin their own interactions with advanced institutes and companies in the industrial economies.

Organization

The 'in-house' management of biotechnology in the IARCs is rooted in this strategy and is still in a formative stage. Centres each have one, two or sometimes three scientists who act as coordinators. They listen to programme needs in the centre and monitor 'the biotechnology world'. The coordinators bring demand and supply together with the help of senior managers who have increasing exposure to contractual, legal and safety concerns. In some centres individuals have been the catalysts in institutionalizing biotechnology with equipment and laboratory space allocated to new techniques. One or two of the larger centres have invested in laboratories and equipment as separate units for their biotechnology initiatives.

Networks

The use of networks to exchange research personnel, techniques and information as a means of acquiring new technologies is extensive in the CGIAR and has found ready application in the field of biotechnology. Research tools are found in both private and public advanced institutions interested in similar problems. Monitoring these collaborative opportunities requires informal networks of professionals who respect each other's views. It requires knowledge of the market ambitions of the private and public sector, and the ability to negotiate with biotechnology proprietors in a creative fashion (Plucknett, Cohen and Horne, 1990). Informal collaborations with scientists in industrial countries also enable the IARCs to explore new and more relevant research techniques. Formal and informal networks, involving both advanced institutes and developing country NARS enable the transfer of both IARC products and new research techniques.

The first biotechnology network is in rice and was established in 1985 with major assistance from the Rockefeller Foundation. It links advanced laboratories in Europe, the United States and elsewhere with the International Rice Research Institute (IRRI) and CIAT. Molecular maps are being developed to allow breeders to determine whether an individual rice plant contains known genes. Many potentially useful genes have been cloned from rice, including the gene 'oryzacystatin', an inhibitor of the digestive enzymes of insect pests (Toenniessen, personal communication, March 1991).

The formation of the Cassava Biotechnology Network in 1988 at CIAT, involving scientists in Latin America, Europe and the United States, brought new techniques to difficult research problems in cassava. Most of the network's research is taking place in developed country university laboratories. Activities include studying the biochemistry and genetics of cyanogenesis.

Social scientists will assist with farming system studies in areas where cyanogenic cassava is grown (CIAT, 1990). Findings will help define research objectives: whether to eliminate cyanide throughout the plant, or to increase specific enzyme activity to reduce the presence of cyanogenic compounds. A further goal is the production of true seed as a joint venture between the International Institute of Tropical Agriculture (IITA) and CIAT. This is sought through the incorporation of apomictic genes to obtain unfertilized embryos. The research will be complemented by a socio-economic study to examine the acceptability of seed as an entirely new planting method for cassava.

The Centro Internacional de la Papa (CIP) and CIMMYT are also effectively using collaborative networks. CIP has established an extensive network of collaborating institutions in the United States, China, Israel and Europe for activities in genetic engineering and RFLP analysis. Efforts such as this have afforded CIP access to scientific expertise in a cost-effective manner. As of 1990, CIP had received over 30 gene constructs at a cost of only US\$60 000 (Dodds and Tejada, 1990). CIMMYT has established the CIMMYT-North/Latin American RFLP Network which will map the genome of maize (Plucknett, Cohen and Horne, 1990). Currently seven US universities, EMBRAPA (Brazil) and CIVESTAN (Mexico) are participating. Network objectives are to examine RFLP's ability to mark quantitative traits, as well as to serve as a marker-assisted selection aid in breeding.

Technology transfer and training

ILRAD is an exception among the CGIAR centres as 'an advanced institute' using biotechnology in the same manner as university and private sector institutions in the industrialized countries. ILRAD's 15 years of research experience incorporating both the traditional and the newer biotechnology techniques have enabled it to demonstrate a degree of bridging with developing country laboratories.

The main goals of the centre are the development of vaccines against theileriosis and trypanosomiasis. These involve recombinant DNA research relevant to analyses of (1) organization and expression of specific genes in both parasite and mammalian hosts; (2) production of antigens to serve as vaccine candidates; and (3) expression of identified genes in bacterial and viral systems. Embryo transfer and embryo splitting is also used for analyses of immune response to parasite infections and for trait/gene mapping to determine the genetic base of resistance (Doyle, personal communication, 1991). Regular training courses and graduate research programmes pass on information and techniques to national programmes and ILRAD scientists provide technical support and expertise at the request of national governments. In 1989, ILRAD participated in national disease-control planning seminars in Ethiopia, Kenya, Tanzania, Uganda and Zimbabwe (ILRAD, 1990).

Across the CGIAR the diffusion of research techniques is actively fostered by the training programmes and the collaborative and consultative networks supported by the IARCs. The 13 IARCs in the CGIAR gave training, mainly short courses in research techniques, to an estimated 25 000 developing coun-

try scientists over the five-year period 1985–9. Research fellowships in biotechnology at the higher degree level for up to two years have been offered at several centres. Most common, however, are short courses. Researchers are trained in aspects of biotechnology before returning to their home institution to apply what they have learned. These same people then become valuable collaborators of the IARCs in future activities with the NARs.

Centres have a responsibility to be aware of the needs of national programme scientists in biotechnology research. CIAT recently surveyed Latin American and Caribbean institutions on their needs for advanced training in modern biotechnology and its application to agricultural problems. Of the 60 national universities and research institutions surveyed, 51 responded. The results from this survey will help CIAT plan for advanced training courses to be offered over a subsequent three-year period (Roca, personal communication, April 1991). Short-term personnel exchanges with developed country institutions, including private laboratories, also help the centres establish the basis for effective collaborations.

Institution building

The Netherlands government commissioned ISNAR to study existing agricultural biotechnology research in Colombia, Indonesia, Kenya and Zimbabwe. These studies are part of a series of studies commissioned in conjunction with the World Bank/ISNAR/Australian government agricultural biotechnology study. Study teams will work with scientists and policy makers to identify opportunities for building biotechnology into national systems. The studies are focused on priorities in research, public- and private-sector investments, regulatory procedures, management of intellectual property and technology transfer in the international arena (ISNAR, 1990). These studies will provide collaborative learning opportunities and guidelines for similar work in other countries.

As a group, the IARCs are hesitant to promote biotechnology training in countries without significant plant-breeding programmes and without appropriate laboratory facilities. Experience shows that researchers returning to a national system with no means of mobilizing the skills learned are frustrated and often become brain-drain candidates. Such outcomes are also a waste of IARC resources. Approaches which lend themselves more directly to commercial investment offer an alternative. In 1986, a biotechnology programme was established by the Andean Development Bank (CAF – Corporación Andina de Fomento). The IARCs in the Latin American region were enlisted to assist in some of CAF's activities on a 'backstopping' basis. A biotechnology unit was established by CAF in Caracas, Venezuela, to work on problems relevant to the Andean region. CIP assists in CAF-supported projects in five Andean countries; Peru, Bolivia, Ecuador, Colombia and Venezuela. These range from the use of tissue culture for improved seed production and virus irradiation to *in vitro* tuber production for seed to facilitate transport of planting materials to remote areas (Dodds and Tejada, 1990).

Examples of direct help for NARs in building biotechnology facilities are few to date. Sigatoka, a devastating fungal disease of plantains, entered Nigeria in 1986 and IITA has since helped establish two plantain and banana tissue culture laboratories there. This is the first large-scale tissue culture operation for production and distribution of planting material in Nigeria (IITA, 1989).

ISSUES IN THE CGIAR'S ROLE IN BIOTECHNOLOGY

Biotechnology has been likened to the microchip – a generic technology with spin-offs to wide areas in both industry and agriculture. Expectations have drawn many developing countries into significant investments in biotechnology R&D. Biotechnologies are perceived to have particular advantages for LDC agriculture: lower cost to research budgets and to farmers, enhanced stability, an 'environmentally friendly' image resulting from less dependence on purchased pesticides and less reliance on sophisticated infrastructure by reducing the volume of inputs to be distributed (Mueesen, 1990).

The CGIAR strategy will help bring these advantages to developing country farmers for the commodities in which it is mandated. Nevertheless, the CGIAR strategy, limited as it is, faces formidable challenges. These demand active and innovative management from individual centres and the system as a whole. At the heart of these challenges is the changing research environment particularly in developed countries.

The changes are driven by dynamic interactions between emerging opportunities in biotechnological research, increasing interest by public research institutions in developed countries in controlling and commercializing research outputs, restructuring of, and closer actions between private and public agricultural research industries, constraints on public research budgets and by an extending domain of intellectual property rights... Inappropriate response to the changes by the IARCs could adversely affect their working relationships with national agricultural research systems, and reduce their attractiveness to research collaborators. (ICRISAT, 1991).

IARCs: future access to biotechnologies

The IARCs experience and expertise in crop improvement is a strong attraction to the private sector. This can be attributed in part to the extensive germ-plasm collections. Each IARC holds a major collection of the germ-plasm for its mandated crops. IBPGR promotes gene banks world-wide, including banks in NARS. It collaborates closely with the CGIAR crop-improvement centres in maintaining their collections. It is widely believed that the value of these collections will escalate as biotechnology expands and the genes they contain gain importance. They represent a major asset for the IARCs in dealings with the private sector. The real strength of the crop-improvement IARCs is in conventional plant breeding. The centres organize global and regional networks for international testing sites and have long-standing collaborative

arrangements for testing and for distribution of materials with national systems in developing countries.

The universities and multinationals in the industrial countries respect these strengths. Yet the IARCs in the CGIAR have traditionally operated an open-door policy. All bona fide clients, whether public or private, in the developed or developing countries, have access to IARC germ-plasm. The IARCs have monitored its use and have to date successfully deterred commercial companies from patenting their materials. The ongoing shift to private sector research in the industrial economies juxtaposed to the advent of modern biotechnology, creates a major dilemma for the IARCs.

It should be borne in mind that current discussions remain hypothetical. Currently no 'economic genes' have been engineered into CGIAR crops. Even when such engineering is achieved, intellectual property rights (IPR) negotiations (and eventual contracts) will be crop- and site-specific. Genetically engineered maize for the US Mid-West will in all probability be unsuitable for Africa. Much of the ongoing discussion is aimed at shaping a CGIAR position.

Orphan crops

It is generally agreed that the IARCs and NARS will have access to private sector biotechnologies for commodities in which there are no extensive markets at stake. The fact that venture capital companies and university initiatives in biotechnology are discrete operations relying on client contracts creates opportunities for the centres as clients and as partners. While access looks feasible, the stock of research experience and the breadth of biotechnology in the so-called 'orphan crops' activity are likely to remain limited. Within this 'orphan crops' group, cassava, sorghum, millet and plantains are of particular importance. The CGIAR may provide the only means of cassava improvement, yet the cost of leadership can already be seen in the investment levels for conventional research. The IARCs currently provide one quarter of the investment in cassava research, with NARS in cassava-producing countries the other three-quarters. That is approximately 400 per cent of the comparative ratio for the IARCs/NARS as a whole (Bertram, 1990). Orphan crops such as cassava have little free-rider potential and the CGIAR costs for similar products in the orphan group of crops are expected to be high.

The private sector is particularly interested in the fact that the IARCs dominate strategic research in the 'orphan crops' group which is already producing sources of genes widely useful in industrial country commercial crops. Such generically useful genes will also be a focus for inter-IARC collaboration. An issue here is how aggressive the IARCs should be in capturing the benefits from multiple-use genes derived from the orphan crops. It seems likely that the advanced institutes see such genes as the major reason for collaboration. Contract prices are likely to reflect the expectations of such benefits and, where IARC germ-plasm is one factor in negotiations, arrangements may be wholly collaborative.

Commercial crops

In terms of access to biotechnologies, the most difficult category of crops for the CGIAR is those important in both industrial and developing economies. Maize, rice, potato and wheat are the major ones. The three cereals listed account for 80 per cent of starch staple food production in the developing world.

The real arena for the IARCs and the private sector is commodities of commercial interest in both industrial and developing economies. The policy debate on reducing subsidies to the agricultural sector of the industrial world threatens the domestic markets of the large agricultural multinationals and increases their interest in new markets overseas. Their biotechnology capacity may become a major bargaining chip for market access in developing countries. In 1980, the Chinese signed an agreement with Ringaroud Seed Products (Occidental Petroleum) and Cargill, giving them the exclusive rights to the production and marketing of hybrid rice in certain parts of the world. Since that time the private companies have pressured the Chinese not to share the information and germ-plasm involved in their hybrids with IRRI. In another case, rather than accept the restrictions imposed by a private company on the use of its research in wheat gene mapping, CIMMYT has sought public sector funding to support wheat gene mapping research in the USA (Barker and Plucknett, 1991).

Intellectual property rights

To date few centres have been exposed to intellectual property issues. In a response to a query from the CGIAR Chairman in November 1989, five centres indicated that they had experience with managing intellectual property. Two centres had patented farm equipment or fertilizer preparations; one shared a patent with a collaborating institution in a developed country; the other two had filed for patent protection, one for a variety, the other for a biotechnologically developed vaccine. None has yet filed for plant variety protection for varieties developed at centres (Barton and Siebeck, pre-print version).

In the context of these discussions, two recent reports (Persley, 1990a; DGIS, Netherlands, 1991) have recommended a break with the open-door tradition. They emphasize that effective bridging of the benefits of biotechnology to the developing countries requires the IARCs to work with the private sector, itself heavily dependent on product protection to earn a return on capital invested in R&D.

If the IARC's adopt a protective strategy and patent their products they can license NARS to use the products without cost. Yet commentators perceive the private sector as nervous about the IARCs' ability to maintain the security of IPR agreements. Can the IARCs ensure that protected products from the private sector will not go astray? Even more difficult is the question of whether the IARCs can condition their own clients, particularly public sector institutions, not to 'leak' products to companies competing in the established

markets of the industrial economies. The private sector badly needs assurance of the security it can expect from the IARCs. Current uncertainty is a major inhibitor to collaboration (Mueesen, 1990). Some see the legal problems of access increasing in intensity as the public universities and private sectors grow closer. Others cite the helpful initiatives by USAID in gaining access through US companies, in part by providing funding for collaborative work (Dodds, personal communication, March 1991). Countries in their roles as donors may provide leverage for the developing countries where damaging restrictions can be anticipated.

A recent report (Barton and Siebeck, pre-print version) commissioned in consultation with the IARC Centre Directors, draws the following conclusions for the IARCs access to biotechnologies and IPR:

- (1) Much of the activity of the centres can continue without intellectual property protection and without breaking the centres' traditions of open scientific exchange. This is appropriate for centres working in countries that have not extended intellectual property protection to plants and biotechnology and for centres whose mandate crops have little commercial interest for industrial country markets.
- (2) As it will be imperative for the centres to continually gain access to new proprietary technologies of potential use to developing countries they will require understanding of patents and licensing. This will also entail acceptance of restrictions on the free inter-system exchange of materials.
- (3) Each centre should carefully review the institutional linkages as to how its innovations reach the farmer, and for protection when marketing the innovations to developing country farmers.

There will be many management challenges to the IARCs as new patterns develop. One particularly difficult area will be in retaining the trust of the NARS in countries with a long-standing concern about the motives of the multinational corporations. It may be that some corporations value the IARCs as a channel for access to developing country markets. The IARCs will have to remain very clear, in a difficult balancing act, that their allegiance remains with developing country farmers. There are concerns, given the highly political nature of the government/multinational interaction in many countries, that the IARCs will occasionally fall foul of the process. Commentators have made a case for centralized support on legal questions accessible by all IARCs (Persley, 1990b; Barton and Siebeck, pre-print version; Beachy, personal communication, 1991).

IARCS and NARS organizational issues

There are organizational issues at each end of the 'biotechnology bridge'. The type of staff the IARCs will need for effective monitoring of biotechnology, given its rate of expansion and increasingly sophisticated applications, may be difficult to attract. Some centres already feel inadequate to evaluate the potential of emerging techniques. Doubts have been expressed about their ability to

hire and retain state-of-the-art molecular biologists. Attracting them away from the 'cutting edge' laboratories, asking them to monitor and implement techniques developed elsewhere, and wondering whether they can keep up with mainstream research while remaining somewhat isolated are serious aspects for consideration. A system of retainers or joint appointments between IARCs and university institutes may be a more viable alternative (Dodds, personal communication, 1991).

Even larger LDCs which have set up full biotechnology laboratories have faced stumbling-blocks. Two barriers seem to be: (1) a failure by governments to complement the new institution with friendly policies to minimize the logistical and licensing problems of importing raw materials and equipment; and (2) the failure of central units to link with the institutions implementing the main R&D process in agriculture. Central units may be effective, if they are vertically integrated with a demand-driven agenda, as well as a channel reaching the rural areas. Many commentators advocating biotechnology investment in LDCs under-estimate the institution building required throughout the R&D process to bring appropriate technologies to farmers. In some cases, where fears of renewed dependency can be allayed, the private sector will offer the less torturous alternative.

The logistics and licensing of imported materials also affect the ability of some IARCs to exploit biotechnology at the molecular level. In IARC host countries new developments in legislation on both bio-safety and IPR will be important. Most centres have internal bio-safety committees and there are adequate guidelines (from the National Institutes of Health, the Animal and Plant Health Inspection Service (APHIS) in the USA and from the EC) on the laboratory conditions for containment in genetic engineering and the field testing of engineered plants. One question still at issue is the release of genetically engineered plants in areas of natural diversity. It will be important to those IARCs deliberately located near centres of origin of their mandate crops. In one or two cases the IARCs have been able to help host countries draw up their own bio-safety codes. It is clearly important that the IARCs operate within the laws of their host countries. As legislation is passed, current memoranda of agreement between host country and centre may be affected.

A LOOK AHEAD

The IARCs are well positioned to contribute to disseminating appropriate biotechnologies to LDC agricultural research. Their strengths are the relevance of their agenda and their growing links with biotechnology in the industrial countries. The IARCs are building these strengths on both sides. On the research agenda side several have recently brought regional groupings of NARS into their priority-setting processes. The result is an increasingly demand-driven CGIAR, using its global perspectives on productivity, equity and sustainability to allocate resources across regionally identified priorities.

Currently there are strong donor pressures on the CGIAR on both funding and programmes. The long-term nature of strategic and applied research brings such pressures when donor domestic budgets are tight. This time it is rein-

forced by other funding needs: the environment, Eastern Europe and the needs of the NARSs themselves. These have drawn attention away from the CGIAR. Yet donors see the CGIAR as successful. They want stronger programmes in three areas — biotechnology, resource management and the environment. They also want greater support to strengthen NARS. These demands pull the CGIAR in opposite directions, upstream to more strategic research and downstream to build adaptive research capacity in the NARS. This contradiction also pervades biotechnology for which the NARS require strong plant-breeding programmes in which the IARCs continue to invest heavily in training.

The CGIAR is planning to restructure itself around two types of research and support mechanisms. Global commodity centres will engage primarily in strategic germ-plasm research, including biotechnology, and limit their training to specialized techniques. Such centres would divest themselves of general training in agronomy and plant breeding and would have direct interactions only with strong NARS. Eco-regional mechanisms will take two forms: first, networks among strong NARS, in which research and training are contracted out to competent institutions in both developing and developed countries; second eco-regional centres for regions dominated by weak NARS. Both mechanisms will assume responsibility for eco-regionally defined resource management research. Centres will have the added responsibility of coordinating CGIAR interactions with the NARS, including institution building and training.

Increasing the scale of CGIAR activities depends on funding, which is part of the larger question on the level of development aid. The rapidly emerging concerns about the environment and global warming demonstrate the overwhelming interdependencies and highlight the global nature of the problem. This may eventually generate the political will to look beyond national boundaries in drawing up the social and environmental cost/benefit evaluations. When this effects the level of development aid the CGIAR should benefit.

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DISCUSSION OPENING – R.E. EVENSON*

In their informative paper Collinson and Wright Platais note that advances in the biological sciences have created important opportunities for agricultural research organizations. Private firms have invested heavily in agricultural biotechnology research. A single chemical company, Monsanto, has 240 senior scientists working on plant and animal biotechnology with expenditures of some \$55 million, and numerous other private firms are engaged in agricultural biotechnology research. Public agricultural research systems in developed countries have been more cautious, but have also invested heavily. It is therefore notable that the authors, in considering the CGIAR, report that about 4.5 per cent of the budget was allocated to plant and animal biotechnology research in 1990. For plant biotechnology, they indicate spending of \$7.5 million (up from \$4.3 million in 1988). This is less than 3 per cent of the CGIAR budget for plant research. Most of this spending is actually 'special project' funding and it is unlikely that core spending on biotechnology is even one per cent of plant research spending in the CGIAR.

One could perhaps understand why many research programmes in developing countries would find it difficult to mount substantive biotechnology research programmes, given staffing and funding constraints. One could also understand the rationale for a 'wait and see' strategy on their part, given the apparently high degree of uncertainty and risk in biotechnology projects. But why should we accept the limited and timid response to biotechnological research opportunities by CGIAR institutions? These institutions cannot argue that funding and staffing constraints have prevented them from making a more vigorous response. Furthermore, they have accepted a responsibility to be the conduits through which developed country scientific advances are made accessible to developing country research programmes and to provide leadership in scientific matters.

Collinson and Wright Platais mention various 'network' activities by IARCs (for example, rice biotechnology at IRRI, cassava at CIAT and IITA, and genetic projects at CIP and CIMMYT). These networks are in sharp contrast to the normal networks by which IARCs convey scientific findings to developing country NARCs. In these networks the IARCs are the recipients, not the initiators.

Collinson and Wright Platais state that the centres have a responsibility to be aware of the needs of national programme scientists and that they are engaged in training and institution building. They note cases of limited capacity to absorb technical assistance by developing countries. They also discuss some of the conflicts with private sector research and the possibilities of limitations of germ-plasm exchange imposed by stronger intellectual property rights.

On the whole, the authors conclude that there are a considerable number of cases of IARC responses to the opportunities and problems inherent in the field. They note a broad degree of awareness and indications of planning and

*Yale University, USA.

prospects for future work, yet, even though they are not highly critical of the IARC response, they do not paint a picture of aggressiveness of leadership.

Plausible explanations for the CGIAR's failure to provide aggressive leadership in this field are:

- (1) that the expectations underlying investments made in developing countries have been unrealistically high;
- (2) that expected biotechnology products are inherently better suited to the market conditions in developed countries and that they will have limited markets in less developed areas;
- (3) that NARCs have a limited 'absorption' capacity for advanced skills and would not be able to benefit from more IARC effort; and
- (4) that the IARCs find a leadership and conduit role in biotechnology beyond their inherent capacity and their own view of their role.

In this reviewer's judgment, the arguments regarding unrealistic expectations and developing country location specificity of biotechnology products have validity and justify caution and a wait-and-see attitude on the part of CGIAR institutions. One would not expect CGIAR institutions to respond to biotechnology opportunities in the same way as leading US universities (and certainly not as Monsanto Chemicals has). However, the timid response actually observed is surely not consistent with the acceptance of the science conduit role by the IARCs.

This inability or unwillingness on the part of CGIAR institutions to respond more aggressively appears to be heavily ingrained in the system and part of a broader set of institutional problems with applied research centres. Over the past 15 years or so, the CGIAR system has responded to exhortations to move downstream to more applied activities such as farming systems research and on-farm research. This move away from science has been seen as a way to exhibit more relevance to the donor community.

The history of agricultural research systems has generally been one of continuous conflict and tensions between the demand-side interests of farm groups pressing for more applied and more relevant research and the supply-side interests of scientists. Productive research systems have managed a complex resolution of most of these conflicts through the development of 'pre-technology' science fields to complement the applied agricultural sciences (Huffman and Evenson, 1991).

The CGIAR system is subjected and has responded to pressures on the demand side for more applied research. It appears to have relatively weak pressures, as yet, to respond to the supply-side opportunities afforded by the sciences. Unfortunately, historical experience with agricultural research institutions, including the US agricultural experiment stations, is that they do not respond to scientific opportunities on the supply side until their applied research programmes reach states of obvious exhaustion. In other words, they do not 'reach upstream' to the sciences until it is clear that their present research efforts are unproductive. Only then do they attempt to convince their 'donors' that they must become more scientific. If this historical experience holds for the CGIAR institutions, we have some time to wait before we can

expect more response to scientific opportunities such as those afforded in biotechnology.

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