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OBJECTIVES AND NEEDS FOR AGRICULTURAL BIOTECHNOLOGY: BIOSAFETY AND INTERNATIONAL COLLABORATION

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ABSTRACT

To derive benefits from biotechnology, research should relate to development needs and offer practical benefits. For Africa, research should focus on improving the quality and standard of agriculture, increasing yield stability, and ensuring sustainable productivity. The desired benefits of biotechnology will only be possible if conventional agricultural research foundations are capable of translating laboratory findings into field applications. This requires that biosafety regulatory structures be put in place.

Key Words: **Agricultural research, biosafety regulatory structures, development needs**

RÉSUMÉ

Pour tirer profit de la biotechnologie, la recherche doit suivre le développement de besoins et offrir des avantages pratiques. Pour l'Afrique, la recherche doit se focaliser sur l'amélioration du niveau et de la qualité de l'Agriculture par l'augmentation de la stabilité de rendement et en assurant une productivité viable. Ceci nécessite la mise en place de structures de biosécurité.

Mots Clés: **Recherche agricole, structures de biosécurité, le développement de besoins**

ADDRESSING FOOD AND AGRICULTURAL NEEDS FOR THE FUTURE

As nations set their food and agricultural targets for the coming decade, they look to satisfy demand by balancing economic and environmental costs of production. In balancing these costs, two resource bases can be utilised. The first is natural resources, including land, water and genetic resources. Future demands and potential for use of these resources indicate increasing cost constraints for agricultural applications (Crosson and Anderson, 1993). With regard to Africa, environmental issues such as land degradation, pesticide pollution, and water scarcity and contamination are often coupled with economic realities and inadequate purchasing power (Norse, 1994). As such, increasing either the use or cost of natural resources poses difficulties for national planners and decision makers in African agricultural research systems.

The second base of resources encompasses human-made ones, defined to include knowledge and innovation. Applications of biotechnology are presented as examples of human-made resources in regard to future needs for food and agriculture. Without the addition of new knowledge and innovation embodied as either people, technology or institutions, the global agricultural system will not meet expected demand scenarios at acceptable economic and environmental costs (Crosson and Anderson, 1993). This is not to minimise the importance of natural resources or their related management practices, but rather to consider the range of improved inputs to complement the natural resource base and their use in agricultural systems.

Finally, expectations regarding the contribution from innovation and new knowledge will be tempered by each country's capacity in conventional agricultural research, including testing, development and diffusion. Advantages to come from biotechnology cannot be at the expense of priority conventional research and should anticipate related biosafety demands. Priorities are needed which rapidly integrate new knowledge with conventional research, support agricultural objectives, and address end-user needs. However, to achieve benefits from such priorities, new technologies must be coupled with appropriate economic policies, infrastructure development, support services and education (Lynam and Blackie, 1994).

The above points are summarised by the following assumptions: (i) continued intensification of agriculture is imperative to meet food needs; (ii) environmental concerns can be partially addressed by sustaining productivity, and; (iii) research to find new pathways for productivity gains is essential (Plucknett, 1994). With these assumptions as a background, this paper examines the benefits expected from innovation, their relation to agricultural objectives and supportive policies including biosafety, and potential for stronger international collaboration.

NATIONAL OBJECTIVES FOR FOOD, AGRICULTURE, AND BIOTECHNOLOGY - MAKING THE CONNECTION

If knowledge and innovation are essential to meet productivity requirements, are such needs reflected in national objectives for food and agriculture? Here, we wish to refer to results from the first of a series of regional policy seminars on biotechnology organised and developed by the Intermediary Biotechnology Service (IBS). This seminar was held in September 1994 in Singapore, and included delegations from Thailand, the Philippines, Vietnam, Indonesia, Malaysia and Singapore. The meeting started by reviewing the most important national objectives for agriculture, then relating these to priorities for crop and livestock improvement, and how biotechnology might contribute to these objectives.

Review of these findings is based on national objectives attributed to the following categories as presented by Janssen (1995): (1) economic growth: research activities which contribute to increasing income levels; (2) equity: distribution of benefits from research across society; (3) food security: ability to feed a population during climatic variability or unstable world pricing; and (4) environment: agricultural resource management, nature conservation and sustainability.

From the meeting in Singapore, it was seen that national agricultural objectives and related planning activities anticipate the need for development and introduction of new knowledge and innovation. Even more relevant, these national objectives include planning for biotechnology (Table 1). Once identified, these objectives were then reviewed in relation to end-user needs and priorities for research. This review reinforced the relation between agricultural and food needs, the development and introduction of new technology, and the economic realities for implementing and financing new research. From a policy and planning perspective, those costs are weighed against other investment and planning strategies for national development. In agriculture, we know that these costs must be undertaken in relation to the other changes expected for the sector, such as those identified by Pinstrup-Anderson (1993): rural infrastructure, agricultural production technology and access to inputs, natural resource management and environmental considerations; and government policies.

Linking research in African countries with international programmes for collaboration is one way to connect research with national objectives. Examples of international biotechnology programmes and their link with national objectives of economic growth, equity, food security and the environment are shown in Table 2. These are taken from the IBS database, BioServe, described later in this report. To sustain this collaboration, finances are required from the

Table 1. National planning objectives and their relation to agricultural objectives in selected Southeast Asian countries*

National Objective	Country	Selected Example
I. Economic growth	Indonesia	Increased production efficiency, anticipating agricultural systems based on more capital investment and reduced labour requirements.
	Philippines	Global competitiveness of agricultural products.
	Singapore	Develop superior varieties to improve productivity and quality of tropical crops.
	Thailand	Improve productivity and adjust production structure.
II. Equity	Indonesia	Promotion of more balanced development among regions.
III. Security	Vietnam	Improving living standards by producing 350-380 kg of grains and 20-22 kg meat per person by the year 2000.
IV. Environment	Indonesia	Preservation and protection of the nation's natural resources through development of sustainable agriculture.

* Examples provided from the IBS database, BioServe (IBS, 1994)

countries themselves to match those available from international sources.

In summary, biotechnology can help meet agricultural needs and objectives. However, this research needs to be connected to national development objectives and policies and end-user needs. Building the connection between increased capacity for people, technology and institutions, national objectives, and end-user needs is essential, regardless of which objectives biotechnology serves. Connecting biotechnology with national agricultural objectives and financing, integrating it with conventional agricultural research and building international collaboration is one way to develop national capabilities.

EXPECTED BENEFITS FROM RESEARCH - THE AFRICAN CONTEXT

A primary expectation from agricultural technologies and interventions is the contribution to income generation. For Sub-Saharan Africa, agricultural production will continue to be a primary source of income and jobs and contribute to gross domestic production. While, in general, regions and countries will become less dependent on agriculture as a source of wealth, African countries are still expected to have 32% of their gross domestic production derived from agriculture in the year 2000 (Norse, 1994). Applications of biotechnology for value-added traits and improving quality and standards will be relevant in this regard.

A second expectation of benefits from genetic enhancement research, including biotechnology, relates to the need for increased yields as well as increased yield stability in diverse African farming systems (Lynam and Blackie, 1994). This contribution would address the fact that 57% of crop production increases for Africa are expected to be obtained from yield increases, 26% still derived from increases in arable land, and 17% from increased cropping intensity (Plucknett, 1994). Applications of biotechnology which sustain or increase productivity, such as for

TABLE 2. National objectives and biotechnology applications*

National Objectives	Research Topic	Biological Focus	Implementing Institutions and Country
Economic Growth: contributions to increasing income levels	Bioreactor methods for axillary shoot bud multiplication; including evaluation of process efficiency, clonal fidelity, and germplasm of local importance.	Pineapple clones, two commercially selected with others determined in the future.	*Fitotek Unggul, Jakarta, Indonesia *DNA Plant Technologies, New Jersey, USA *ABSP, Michigan State University, USA
Equity: benefits across society	Production of live recombinant virus vaccines for livestock diseases, particularly those needed by subsistence or nomadic herders.	Rinderpest vaccine virus vaccines for East coast fever Anaplasmosis/Babesiosis and Trypanosomiasis.	ILMB, University of California, USA *KARI, Kenya; NVI, Ethiopia; Egypt and others * ILRAD, Kenya *CIRAD, France *AB Network Project, USA
Food Security: food available during unstable climate or pricing	Production of virus-resistant, clonally propagated planting material for African farmers.	Feathery mottle virus resistance in African sweetpotato.	*KARI, Kenya *Monsanto, USA
Environment: resource management, conservation and sustainability	*In vitro* germplasm conservation.	Conservation of various clonal and tuber crop and wild relative germplasm	*International agricultural research centres, global *National germplasm systems in *developing countries *CATIE

* Examples provided from the IBS database, BioServe (IBS, 1994); also contains full names of abbreviated institutions.

improved disease or pest management, are relevant here.

A third benefit relates to considerations of environment-production complementarity. Sustainable agriculture can be used as an objective for research approaches focusing on the long-term physical and social effects of technologies and their more immediate implications for productivity and the economy (Salvador *et al.*, 1993). Agricultural research using biotechnology can be linked to sustainability, thus directing applications of research towards environmental considerations. In this way, biotechnology contributes to pressing environmental issues by providing new inputs for use in sustainable agricultural systems.

BIOTECHNOLOGY: INNOVATION AND INTERNATIONAL COLLABORATION

Biotechnology provides agricultural systems with the potential for greater productive use of biological and genetic resources. The set of tools which comprise biotechnology offers the opportunity for more efficient and specific modification of plant, animal and microbial genomes. These advances must be seen as part of the agricultural research continuum, requiring a firm foundation of conventional agricultural research in order to move results from laboratory to the field. In the context of the integration of agricultural biotechnology into conventional breeding, Day (1993) has identified the following areas of practical accomplishments from biotechnology: (1) transformation, gene isolation and cloning; (2) mapping and marker assisted selection; (3) micropropagation and tissue culture; (4) hybrid seed production; and (5) control of gene expression.

Rapid developments in the above-mentioned areas are prompting developing-country governments to initiate either national programmes or to stimulate new research targets for agricultural biotechnology. Growing numbers of governments are making investments in infrastructure and human resources to support this research, and are adopting policies to facilitate biotechnology research and development in both the public and private sectors. Linking expanding interests in the application of the above-mentioned technologies to specific agricultural needs and objectives is a challenge faced by decision makers and researchers in developing countries.

This raises a diverse set of issues and questions for decision makers, such as: how have the needs and priorities for biotechnology been determined in relation to agricultural objectives? Are the necessary guidelines in place for the safe application of biotechnology? Are the national intellectual property rights laws adequate to promote international collaboration and investment in this area? What are the likely financial requirements for research in agricultural biotechnology?

To better understand emerging needs of developing countries with regard to biotechnology planning, and to assess the potential for collaboration with international research programmes, a meeting was organised by the IBS at the International Service for National Agricultural Research (ISNAR), in The Hague, the Netherlands. For this conference, information was collected from 40 international agricultural biotechnology programmes. These included: (1) research programmes for crops or livestock at national or international public institutes; (2) advisory programmes which concentrate on policy and research management issues; (3) international or regional biotechnology networks for specific crops or regions; and (4) bilateral or multilateral donor programmes which support international biotechnology activities.

Each of these programmes aims at facilitating developing countries' access to modern agricultural biotechnology. They conduct, fund, or coordinate collaborative research focusing on developing country agriculture. Information was collected first from identified international programmes as they can be primary providers of technology, information and collaboration for national programmes in developing countries. Three different survey forms were designed for the identified programmes, networks, and donor agencies, that requested information on: (1) general logistical information and overall goals and priorities; (2) agricultural research focus in terms of crops, livestock species, livestock diseases, or others; (3) regional focus and collaborating institutes from developed and developing countries; (4) type, number and location of training opportunities provided; (5) activities and methods developed in programme planning, policy and management; (6) information products and services; (7) support for infrastructure development in developing-country programmes; (8) research and development projects, their status, and technology transfer channels; and (9) funding sources and expenditures.

A broad range of research and development projects, incorporating accomplishments in the five main areas identified by Day (1993), is being supported by the international agricultural biotechnology research programmes and networks identified by IBS (1994). With regard to crop transformation, Table 3 presents nine general categories of application and specific examples of objectives within these categories. The second column primarily summarises research being conducted in industrialised countries. To compare this information with current research focussing on developing-country agriculture, the third column provides examples of research objectives targeted by international programmes. It can be seen that research in the international programmes concentrates particularly on plant resistance to viruses and insects.

PRODUCTS FROM INTERNATIONAL COLLABORATION IN RELATION TO BIOSAFETY

For a growing number of developing countries, collaborating in international research programmes for agricultural biotechnology offers a range of opportunities for acquiring access to specific technologies and training programmes. Table 4 gives examples of collaborative crop and livestock projects in agricultural biotechnology in which African institutions are participating. Most activities to date are concentrated in Kenya, Zimbabwe, and Ethiopia.

Some of these projects do not require specific provisions with regard to biosafety, such as those involving mass propagation and diagnostics. However, quite a number of projects will eventually yield genetically-engineered crop varieties or recombinant livestock vaccines, which generally require consideration with regard to biosafety regulations for laboratory work, greenhouse tests, field trials, and, eventually, consumer safety assessment. For example, the International Laboratory of Molecular Biology for Tropical Disease Agents (ILMB) at the University of California, developed a recombinant DNA (rDNA) vaccine for rinderpest. Field trials of the vaccine are under way in Kenya and are planned for one other country. Guidelines for the field trials were defined by a joint committee consisting of the UN Food and Agriculture Organisation (FAO), the UN World Health Organisation (WHO), and the Office International des Epizooties (OIE, Paris) (Fitzgerald, 1994).

In the survey conducted by IBS, programmes were asked to indicate progress for their research activities. Progress was charted through seven stages of application. The first three described progress achieved in the laboratory and greenhouse. The next three stages include testing, beginning with quarantined or contained testing and moving to randomised field designs and multi-year tests. Finally, each programme was asked if a commercial or public partner had been identified with regard to technology transfer and product development as relevant for the particular research activity. The results of this analysis are shown in Table 5.

Progress along this continuum is important in relation to a number of considerations. First, it gives an indication of the expected time involved in bringing new developments to the field, it identifies which countries should prepare for a safety review process, and which crops and/or ecosystems may be affected. Table 5 shows that, apart from the rDNA rinderpest vaccine, other products which will shortly be ready for field testing in Africa include recombinant vaccines for anaplasmosis and foot-and-mouth disease, and disease-resistant potato varieties.

As can be seen in Table 6, between 32-39% of the field releases approved in OECD countries have been for herbicide tolerance, while the international programmes have no activities in this area to date. However, in terms of virus and disease resistance, there are 54 project applications identified, 26 for insect resistance and 24 for quality-related traits. If success rates leading to field trials are similar for the international programme efforts as they have been in the

TABLE 3. Cloned genes of interest for crop improvement and applications of international biotechnology programmes

General category	Specific examples[1]	International Biotechnology Programme Application[1]
Disease resistance viruses	° Virus coat protein subunits (TMV, cucumber mosaic, potato virus X) ° Potato leaf roll virus ° Potato virus S ° Soil borne wheat mosaic virus ° Plum pox virus ° Tomato spotted wilt virus ° Viral replicase gene (PVX)	° African cassava mosaic virus, common cassava mosaic virus ° bean gemini viruses ° rice stripe virus, yellow mottle virus, tungro virus, ragged stunt ° potato virus X and Y ° tomato yellow leaf curl virus ° sweet potato feathery mottle virus ° groundnut stripe virus, Rosette virus, and clump virus
Fungal diseases	Chitinase gene, *H1* gene for resistance to *Helminthosporium carbonum* from maize, systemin gene - a peptide signal molecule which controls wound response in plants, infectious viral cDNA	° potato late blight ° rice blast
Insect resistance	*Bt* genes, cowpea trypsin inhibitor, wheat agglutinin gene for resistance to European corn borer	° *Bt* toxin genes applied to borers in maize, rice, sugarcane, potato, coffee ° potato glandular trichomes ° sweet potato weevil ° pigeonpea: *Helicoverpa* and podfly
Storage protein genes	Wheat low molecular weight glutenin gene, maize storage protein	no applications reported
Carbohydrate products	Polyhydroxybutyrate as an alternative to starch for the production of biodegradable plastics	no applications reported
Ripening	Antisense polygalacturonase in tomato, regulation of ACC synthase gene	no applications reported
Breeding systems	Self-incompatibility genes from Brassica, anther specific genes used for male sterility with a ribonuclease gene	no applications reported
Flower colour	Petunia, Antirrhinum	no applications reported
Herbicide resistance	Glyphosate, bialaphos and, imidazolinone resistance.	no applications reported

[1] General categories and specific examples from Day (1993).

[2] Examples from IBS BioServe data base of international agricultural biotechnology programmes.

TABLE 4. Collaboration in biotechnology research with selected countries in Sub-Saharan Africa[1]

Country	R&D Category	R&D Activity	Programme
Ethiopia	Animal health	Vaccine for peste des petits ruminants	CIRAD - MIPA
		Vaccine for contagious caprine pleuropneumonia	CIRAD - MIPA
		Vaccine for contagious bovine pleuropnomia	CIRAD - MIPA
		Recombinant rinderpest vaccine	ILMB
		Diagnostic kit for rinderpest	ILMB
Kenya	Animal health	Recombinant rinderpest vaccine	ILMB
		Diagnostic kit for rinderpest	ILMB
		Diagnostic tests for tick-borne diseases	ILRAD-1
		Recombinant vaccine for East Coast Fever	ILRAD-1
		Vaccine development for trypanosomiasis	ILRAD-1
		Diagnostic tests for trypanosomiasis	ILRAD-2
		Vaccine for contagious caprine pleuropneumonia(CCPP)	SR / CRSP
		Identify vaccine genes for Haemonchus contortus	SR / CRSP
		Vaccine for Nairobi sheep disease	SR / CRSP
		Recombinant vaccine for heartwater	TDV
		Diagnostics for heartwater	TDV
		Diagnostics for anaplasmosis	TDV
		Diagnostics for bovine babesiosis	TDV
		Recombinant vaccine for anaplasmosis	TDV
		Recombinant vaccine for bovine babesiosis	TDV
	Crop productivity	Mass propagation of coffee through somatic embryogenesis	CIRAD - MICAP
	Crop protection	Development of transgenic maize using Agrobacterium-mediated system	ABSP
		Genetic engineering of sweet potato for insect resistance	ABSP
		Genetic engineering of sweet potato for resistance to feathery mottle virus	AID-1
		Genetic engineering of coffee with *Bt* toxin genes for resistance to leafminers and caterpillars	CIRAD - MICAP
Uganda	Crop productivity	Mass propagation of coffee through microcuttings	CIRAD - MICAP
Zimbabwe	Animal health	Molecular probes and PCR to identify mycoplasmosis	CIRAD - MIPA
		Monoclonal antibodies to identify mycoplasmosis	CIRAD - MIPA
		Recombinant vaccine for heartwater	TDV
		Diagnostics for heartwater	TDV
	Crop protection	Cassava transformation for resistance to African Cassava Mosaic Virus	ILTAB
		Cassava transformation for resistance to Cassava Common Mosaic Virus	ILTAB

[1]ABSP = Agricultural Biotechnology for Sustainable Productivity; AID-1 = Sweet Potato / Feathery Mottle Virus Project; BC / CRSP = Bean-Cowpea Collaborative Research Programme; CIRAD-MICAP = Centre de coopération internationale en recherche agronomique pour le développement - Plant Breeding Division; CIRAD-MIPA = Centre de coopération internationale en recherche agronomique pour le développement - Animal Health Division; ILMB = International Laboratory of Molecular Biology for Tropical Disease Agents; ILRAD-1 = International Laboratory for Research on Animal Diseases - Tickborne Disease Programme; ILRAD-2 = International Laboratory for Research on Animal Diseases - Trypanosomiasis Programme; ILTAB = International Laboratory for Tropical Agricultural Biotechnology; ISAAA = International Service for the Acquisition of Agri-Biotech Applications; SR / CRSP = Small Ruminant Collaborative Research Support Programme; TDV = Tickborne Diseases Vaccine Programme

TABLE 5. Analysis of development needs associated with international projects in agricultural biotechnology

Stages of research	No. of projects reported	Illustrative examples relevant for African countries	Critical development needs
Laboratory			
Experimental	15	° Transformation of sweet potato for resistance to feathery mottle virus ° Coffee transformation with *Bt* toxin genes for resistance to leafminers and caterpillars ° Vaccine for trypanosomiasis	*Infrastructure *R&D collaboration
Routine	3	° Sweet potato transformation or resistance to sweet potato weevil ° Tomato transformation for resistance to tomato yellow leaf curl virus	*Scale-up of research effort *Integration *Socio-economic review
Greenhouse			
Screening/Selection	25	° Cotton transformation through *Bt* toxin genes or protease inhibitor genes for insect resistance ° Cassava transformation for resistance to African Cassava Mosaic Virus and Common Mosaic Virus	*Greenhouse or contained facilities *Biosafety considerations *Quarantine relations
Testing/Evaluation			
Contained or Quarantine	5	° Vaccine for peste des petits ruminants ° Vaccine for heartwater	*Biosafety review collaboration
Randomised Field Tests	1	° Vaccine for East Coast Fever	*Biosafety review collaboration
Multi-Year Testing	8	° Potato transformation for resistance to late blight ° Introduction of coat-protein genes for resistance to potato viruses X and Y ° Rinderpest vaccine	*Agronomic and economic evaluation *Cost-benefit analysis
Technology Transfer; Product Development	2	° Foot-and-mouth disease vaccine ° Vaccine for anaplasmosis arrangements	*Private sector linkages *Brokering/intermediary *Technology transfer agreements

Note: Analysis based on 59 distinct projects which involve rDNA techniques in crops or livestock research.

industrialised countries, then the number of field release approvals in tropical countries will need to increase drastically.

DEVELOPMENT NEEDS IN AFRICAN COUNTRIES - POSSIBILITIES FOR INTERNATIONAL COLLABORATION

Policy makers in countries where biotechnology research is conducted, and transgenic organisms are developed, tested, imported, exported or used, should investigate the need for developing a biosafety regulatory structure. This is often induced by international as well as national developments. First, the presence of an effective biosafety system can become a condition for international collaboration. Donor-funded, international collaborative research programmes often contain specific requirements for biosafety. For projects sponsored by USAID, for example, it is mandated that the country of the collaborator have a regulatory structure in place, before the exchange of transgenic materials can take place. Secondly, an increasing number of national institutions are already set to release transgenic organisms into the environment, some in Africa (Feresu,1993). This has created an immediate need to establish biosafety structures, in order to encourage progress in national research. Feresu concludes for Zimbabwe that "It appears as though the developments in biotechnology are currently overtaking those in the adoption and implementation of the biosafety guidelines."

Some countries in Africa, notably Egypt, Kenya, South Africa and Zimbabwe, are developing oversight mechanisms for biotechnology, and these have been described by Wafula (1993). The same author lists a number of complications surrounding the establishment of regulations in Africa which have made progress in this area rather slow. These are: (1) different research agendas and definitions of safety among institutions involved; (2) lack of awareness and knowledge of what goes on in the country; (3) lack of coordinated regulatory structures; (4) lack of finances to support regulatory structures; (5) lack of safety expertise and confidence in decision-making; (6) lack of clarity on principal responsible body; and (7) apprehension that too many regulations will stifle scientific innovations.

A range of international initiatives in agricultural biotechnology are addressing these constraints. Table 7 shows the various activities in biosafety supported by international agricultural biotechnology programmes. They provide advice on specific cases and guidelines, and promote training in this area through individual internships and workshops. In addition, they can be a source of information for national programmes, as many of them have established a programme-specific approach in biosafety. This will complement the "hands-on" regulatory experience that national programmes are gaining, as the number of field tests increases.

In Africa, recent initiatives which illustrate the role that international agencies can play in

TABLE 6. Summary of field release approvals granted

Traits	Approvals granted		
	Percent of Total (1992)[1]	Percent of Total (1986-92)	Number of International Projects [2]
Herbicide tolerance	32	39	-
Use of markers	7	30	12
Virus and disease resistance	22	12	54
Insect resistance	13	7	26
Quality traits	21	6	24
Multiple traits, unspecified, others	5	6	7
Total releases involves	100%	100%	—
Total estimated applications	—	—	123

[1]Percentages taken from Goy *et al.* (1994)
[2]IBS Data base (IBS, 1994)

developing biosafety policies and infrastructure include: (1) establishing a regional focal point for Sub-Saharan Africa for information collection and the exchange. This will be located at the Biotechnology Research Institute of Zimbabwe's Scientific and Industrial Research and Development Council (SIRDC) and is supported by the Netherlands' Special Programme Biotechnology and Development Cooperation. Establishing a focal point was one of the recommendations of a regional conference organised by the Special Programme; (2) the Ministry of Agriculture in Nigeria recently co-organised a biosafety workshop together with the Biotechnology Advisory Commission (BAC) of the Stockholm Environment Institute (SEI). The implementation of national guidelines has been initiated as a result of the workshop; and (3) the Agricultural Biotechnology for Sustainable Productivity (ABSP) programme manages a collaborative project between the University of Arizona (USA) and the Agricultural Genetic Engineering Research Institute (AGERI) in Egypt, to construct a contained greenhouse facility at AGERI. This will provide a suitable environment for the evaluation of transgenic plants.

TABLE 7. Biosafety activities supported by International Agricultural Biotechnology Programmes

Type	No. of activities or methods developed
External advice / guidelines	7
Training / internships	2
Workshops / seminars	8
Information exchange	3
Programme-specific approach	15
Other	1

SUSTAINABLE PRODUCTIVITY

Shall we realise gains and benefits from agricultural biotechnology in international agricultural research? While a case has been made that application of biotechnology can contribute directly to agricultural and social objectives, national financing and planning decisions are required to bring these applications to fruition. The cost of such development is high. The number of applications adopted for development must be realistic. Without such control, numerous activities will be started with the potential for only a very few to achieve development. This will jeopardise future investment and support for agricultural research.

Looking globally for a movement, we recognise an overall pattern of increasing interdependence across all sectors of the food industry (Gaull and Goldberg, 1994). This interdependence is one approach which research and development ventures have adopted to confront the current difficulties and concerns associated with genetically engineered food and agricultural products. These concerns include safety issues regarding use of engineered products in the agricultural or consumer environment, possibility that bioengineering creates high-input-cost speciality crops and animals suitable for only large scale producers, and difficulties faced in getting products to market (Gaull and Goldberg, 1994).

Taken together, this global trend towards interdependence on the one hand, and the realities presented above regarding the costs of development and regulation of biotechnology in African countries on the other, pose a challenge to the international community. Can we compliment one another's efforts and mobilise resources so that agricultural needs and research priorities, including biotechnology, are approached in an interdependent manner as well? This would take advantage of the wealth of information available from the national and international programmes described in this report, to provide a starting-point for policy coherence, and create incentives for interdependence in agricultural sectors relevant to the food needs of Africa.

New technology alone is not sufficient to address agricultural growth. However, preparing for its uptake, integration and use in agricultural research will mean that African countries can look beyond either increasing land and/or cropping intensity for more productive agriculture. In this regard, sustainability can provide a context for biotechnology, as long as both are built on a well-maintained foundation of conventional agricultural research. Facilitating the development of biotechnology by creating capacity in people, technologies and institutions, provides an opportunity for catalysing new knowledge and innovation, which in turn provides a base for interdependence and international collaboration.

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