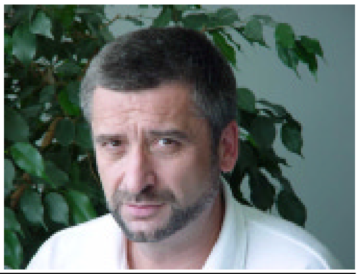

Dr. Manfred Kern

PLANT BIOTECHNOLOGY: PERSPECTIVES FOR DEVELOPING COUNTRIES BETWEEN 2002 AND 2025

Manfred Kern[1]

ABSTRACT

In the first 30 years of the 3rd millennium, the global demand for food will double. In order to produce enough food and to ensure good harvests, farmers everywhere in the world need a reliable source of good-quality seed. Access to improved seeds, adapted to local conditions, will be the key to achieving sustained intensification of food production. Crop improvement by means of biotechnology has now become a reality. The *"globalisation of biotechnology"* is underway. Although the potential of biotechnology is now quite well known, and indeed was advocated in Agenda 21 as early as 1992, progress in the development, realization and utilization of genetically modified crops in many developing countries is far too slow. By reorganizing plant DNA resources, it will be possible to improve the carrying capacity of the Earth. Innovative and vigorous forms of public-private collaboration are required if the benefits of modern biotechnology are to be brought to all of the world's people; incentives are needed to encourage commercial research companies to share with the public sector more of their capacity for innovation. *"Making New Technologies Work for Human Development"* [1] will be a sustainable guideline for responsible people shaping our future, because: *"Mankind is at the Crossroads"*.

Key words: food, transgenic plants, functional genomics, biotechnology strategy, scientific apartheid, technology transfer, private-public partnership

FRENCH

LA BIOTECHNOLOGIE VEGETALE: PERSPECTIVES D'AVENIR DES PAYS EN DEVELOPPEMENT ENTRE 2002 ET 2025

RÉSUMÉ

Au cours des 30 premières années du 3ème millénium, la demande mondiale en nourriture va doubler. Pour produire assez de denrées alimentaires et assurer de bonnes récoltes, partout dans le monde les agriculteurs ont besoin d'une source sûre de semences de bonne qualité. L'accès à des semences améliorées, adaptées aux conditions locales, sera la clé pour atteindre une intensification soutenue de la production alimentaire. L'amélioration des denrées alimentaires au moyen de la biotechnologie est devenue maintenant une réalité. La *"mondialisation de la biotechnologie"* est en cours. Bien que le potentiel de la biotechnologie soit maintenant assez bien connu, car en effet il a fait l'objet de plaidoyer dans Programme 21 en 1992, le progrès dans l'élaboration, la réalisation et l'utilisation des denrées génétiquement modifiées dans beaucoup de pays en développement est beaucoup trop lent. En réorganisant les ressources végétales d'ADN, il sera possible d'améliorer la capacité de la terre de les porter. Des formes novatrices et vigoureuses de la collaboration entre les secteurs public et privé sont indispensables afin que les avantages de la biotechnologie moderne soient à la portée de toute la population du monde entier; les stimulants sont nécessaires pour encourager les entreprises de recherche commerciale à partager davantage avec le secteur public leur capacité d'innovation. "Making New Technologies Work for Human Development" [1] (Mettre les Nouvelles Technologies au service du Développement Humain) sera une directive viable pour des gens responsables qui façonnent notre avenir, parce que "l'humanité est au Carrefour".

Mots clés: nourriture, plantes trans-géniques, génomique fonctionnelle, stratégie de la biotechnologie, apartheid scientifique, transfert de la technologie, le partenariat entre les secteurs privé et public.

[1] Aventis CropScience (in future: Bayer CropScience)
Industrial Park Höchst, K607 D-65926 Frankfurt/Main, Germany
Email: Manfred.Kern@BayerCropScience.com

INTRODUCTION

At the end of the second millennium, only 0.26% more food was produced on the globe than was actually consumed [1]. Elimination of hunger for 840 million people was not achieved. At the beginning of the 3rd millennium, global demand for food will double in the next 30 years. Consequently, crucial questions must be answered: *"How can we feed the future world population in a sustainable way and keeping with human dignity?"* [2], *"Who will be fed in the 21st century?"* [3], and *"What can or must be done by whom to react to changes in time?"* [4].

Although the potential of biotechnology is now quite well known, and indeed was advocated in Agenda 21 as early as 1992, progress in the development, realisation and utilisation of genetically modified crops in many developing countries is far too slow. The quantitative contribution of biotechnology and genetic engineering to world food security - not the elimination of hunger - in the different regions of the world can be outlined as follows: in the year 2025 the developed world (the USA, Europe, Australia, Canada, CIS) will produce 28% of its food using genetically modified organisms (GMOs). Asia will produce 20% of its food supply using GMOs, Latin America 17% and Africa around 6% [5,6].

The uneven diffusion of technology - both old and new - is well documented in the UNDP report 2001 [1]. If developing countries have no or only limited access to biotechnology as such, they will increasingly fall behind industrialised nations. They run the risk of missing out on potential opportunities in the field of biotechnology. Ismail Serageldin, former chairman of CGIAR (Consultative Group on International Agricultural Research) has described this as *"scientific apartheid"* [6].

If the introduction of biotechnology in Africa is delayed, its contribution will be a mere six percent by 2025 [5]. There are two reasons for the small share of GMO-based seeds and plant stock in Africa:

(i) Biotechnology has difficulty finding lucrative market segments in African countries. When introducing this technology, private firms concentrate on profitable markets, notably in the industrial countries [5].
(ii) In the EU the risks associated with GMOs are the subject of much debate and controversy. The conclusion drawn from this is that, as long as the risks associated with these technologies are not 100% clear, there should be no transfer of these technologies to developing countries [5,6].

The book titled: *"Der Preis der Sattheit - Gentechnisch veränderte Lebensmittel"* (Price of Repletion - Genetically Modified Food) written by Pinstrup-Andersen and Schiøler in 2001 [7] describes the mistaken ideas many consumers and consumer associations - especially in Europe - have about the potential of biotechnology for developing countries. Consumer societies, organizing their own passiveness and faint-heartedness, should not make decisions for developing countries [8].

Paarlberg concluded that it is somewhat discouraging to see in so many cases that the most important stakeholders - poor farmers with families to feed - have not yet been given official permission to use biotechnology for raising farm productivity [8].
"Well-fed people in the developed world may have problems, but hungry people in the developing world have only one - how to feed themselves and their families. Well-fed people may engage in lengthy debates about the real or imagined risks of the use of genetically modified crops. Hungry people see crops produced by biotechnology as food. It is abundantly clear that if governments halt the growth of this technology, poor countries will be denied an important solution to the lack of food security" is a clear and remarkable statement made by Thomson [9]. Thembitsha Joseph from Buthelezi, South Africa described the situation in the following words: *"In the West, people have the luxury of being afraid of biotechnology, but for us it's a question of life or death"* [10].

CONVENTIONAL PLANT BREEDING

A vital component for sustainable farming is seed. In order to ensure good harvests, farmers everywhere in the world need a reliable source of good-quality seed. Access to improved seeds, adapted to local conditions, is the key to achieving sustained intensification of food production. The corresponding advances in the field of biotechnology and genetically modified plants will come from both the public sector and, increasingly, from the private sector.

The quality/technology resides in the seed itself - farmers do not even have to change their traditional farming methods in order to achieve better yields. But what are we proposing to do? How can these key technologies be made available to small farmers? What improvements in plant attributes are needed and are beneficial in the long term?

The kind of seed farmers need must be selected with a view to its suitability for sowing on their particular land. Before it can be made available in large quantities, it must be also thoroughly tested on that land. Improved hybrids or varieties are useless unless a sufficient quantity of seeds are available to the farmer, or if they do not conform to high standards of quality and purity.

Many crop species that are important for developing countries are not of much interest to multinational seed companies, even to those with operations in developing countries. That is why it is important to support the setting up of national or regional seed industries, both in the public and the private sector. The resulting seed improvements will bring considerable benefits to small farmers in particular. In many African countries, the dependency on imported main food crops is between 65 and 100%, and in most of them it exceeds the 90% level [11]. Since countries in such regions lack large efficient *in situ* (gene bank) collections as well as a broad base of modern varieties of these major food crops, future agricultural development will clearly require secure access to the germplasm of non-indigenous crops such as maize (centre of diversity: Central America), cassava (South America), wheat (Near East), rice (Indochina), beans (Central and South America), plantain and banana (Indochina), and potato (South America). Africa is not unique, however, in having a food system based on crops with foreign origins. Almost all regions of the world are in a similar situation [11].

Regarding the flow of germplasm between different countries, Fowler *et al.* [11] have summed up the position as follows:

(i) Developing countries have been, and still continue to be, net recipients of a large amount of germplasm samples from gene banks and breeding programmes of IARCs (International Agricultural Research Centre). They receive substantially more germplasm samples from CGIAR gene banks than they themselves supply, a situation likely to become even more pronounced in the future.
(ii) Developing countries receive significantly more germplasm samples from the gene banks than do developed countries.
(iii) Germplasm samples from CGIAR gene banks and crop programmes appear to be distributed to private companies only to a minor extent for most of the crops studied.
(iv) A massive amount of improved germplasm is following in nursery shipments from centre breeding programmes to developing countries.

The authors conclude that continued facilitated access to germplasms in today's world is a *'win-win'* situation for all, and one that is particularly important for developing countries.
Germplasm transfers in the past often aimed at crop introduction, whilst recent flows are generally directed to conventional crop improvement. In future it will be essential to have access to modern biotechnology and genetic engineering technologies.

Genetic Modification (GM) technology, coupled with important developments in other areas should be used to increase the production of main staple foods, improve the efficiency of production, reduce the environmental impact of agriculture, and provide access to food for small-scale farmers.

MODERN PLANT BIOTECHNOLOGY

Crop improvement using biotechnology has now become a reality. The estimated global area of transgenic or GM crops for 2001 is 52.6 million hectares [12].

For 2002, it is expected that GM crop plantings in USA/Canada will suddenly rise to a record level, because farmers there are spending less on inputs such as plant protection products and fuel. The *"globalization of biotechnology"* is underway, especially if commercialisation of GMOs takes place in Indonesia, India, and Brazil in 2002. This would have the result that GMOs will be grown in countries where more than 50% of the global population are living.

Agricultural biotechnology is expected to contribute significantly towards poverty reduction and food security in different regions of the world - especially in Asia, where 2.8 billion people live on less than $US 2 a day - through increased productivity, lower production costs and lower food prices, and improved nutrition [13]. Biotechnology is not a panacea for solving the world's hunger problem, and it will not be able to eradicate hunger - hunger has dozens of *'fathers'*, most of them man-made.

The positive contributions of agricultural biotechnology to alleviating poverty and improving food security for small, medium-sized and big farms have been well described in the meantime [13-24].

Studies in Mexico, China, Kenya and more African countries [11-13, 25-27] have shown that the new technology and the new products were readily adopted by farmers. The "quality/technology is in the seed" and farmers do not need to alter their traditional farming practices to obtain tremendous benefits. Insect-resistant cabbage, for example, is not cultivated in any other way than non-insect-resistant cabbage. Insect-resistant cabbage is, however, not devoured by cabbage moths and thus safeguards the harvest [4].

Furthermore, estimates of national economic advantages to farmers planting transgenic crops as well as the distribution of economic surplus between farmers, technology developer, seed supplier, and consumers are well documented [27-30].

Unfortunately, the speed of development, implementation and utilization of genetically modified crops in the developing countries is unsatisfactory.
The status report of the Twenty-Sixth FAO Regional Conference for the Near East held in Tehran, Islamic Republic of Iran, March 2002 summarised the situation under the following points [31]:

(i) Biotechnology could solve many of the constraints that limit crop livestock, forestry and fishery production in the Near East.
(ii) Priority setting in the region should involve various stakeholders and take into account national development policies, private sector interests and market opportunities.
(iii) Partnerships between foreign and local institutions can assist in the transfer of know-how and help to mitigate the patent requirements.
(iv) It is imperative that developing countries of the Near East region should not be left at the edge of development or placed at a disadvantage. No further comment is necessary here!

A status report on plant biotechnology would turn out to be similar in many African countries.

However, there are positive examples. At the beginning of 2002, in laboratories and greenhouses throughout the globe, several hundred genetically modified plants are being optimised in both developed and developing countries [25]. In China alone, between 1996 and 2000 there were 251 cases of GM plants [25]. The current goal for Chinese investments is to create a modern, market-responsive and internationally competitive biotechnology research and development system [32]. China intends be a source of plant biotechnology for its own farmers and for farmers in the rest of the world, as claimed by Huang *et al.* [25]. China will become an exporter of biotechnology research methods.

Meanwhile, more than 2000 Chinese scientists have identified over 50 plant species and more than 120 functional genes for plant genetic engineering. China's total investment in plant biotechnology in 1999 was estimated to be $US 112 million (about 9.2% of the national crop research budget). The total benefits of Bt cotton sown areas were $US 334 million in 1999 [25]. In 2001, James reported, that the number of farmers that benefited from GM crops increased from 3.5 million in 2000 to 5.5 million in 2001 [14]. More than three-quarters of the farmers who benefited from GM crops in 2001 were low-resource farmers planting Bt cotton, mainly in China and in South Africa.

However, everyone should be aware that the genetic code is a gigantic biological manuscript, which we have only just started to investigate and decipher. One of the principal objectives is to determine the functions of genes in silico (computer modelling) *in vitro* and *in vivo*. This applies to plants from the First to the Fourth World.

More than 20 organisms have already been fully deciphered genetically. The genome of virtually all-major crop plants will have been analysed within the next five to ten years [33].

Functional genomic research will help us understand how the genome determines the phenotype. Marker-supported seed development will be a basic instrument for future seed improvements. It will enable the development time for seed to be reduced from ten or twelve years to less than five years. Improved characteristics in terms of specific climatic conditions and locations can then be introduced more rapidly into high-yield varieties.

Seed optimization will be increasingly adapted to future requirements by new strategies and tactics, which will be developed largely as an outcome of functional genomic research [33].

By reorganizing plant DNA resources, it is possible to improve the carrying capacity of the Earth. If poor people in the developing countries were given direct access to modern technologies (biotechnology, genetic engineering), they could significantly improve their own lives and the natural environment in which they live. However, for developing countries to be able to use genetic engineering for country-specific or region-specific purposes, they must be given direct access to the techniques and methods of genetic engineering. Certainly, the implementation of new technologies has to respect and reflect social, political, ecological and economic aspects.

At the beginning of 2002, in laboratories and glasshouses throughout the globe, several hundred genetically modified plants are being optimized with a view to impending climatic aspects. Many of them will be used in the foreseeable future, both in developed and in developing countries.

Biotechnology will produce plants with characteristics such as resistance to drought, heat, cold, salt and pathogens, thus enabling them to be cultivated even in extreme localities. The following examples were taken from an overview made by the author in 2002 [4].

In South America, particularly in Peru and Bolivia, attempts are being made to modify potatoes genetically to make them tolerant to cool temperatures or frost.

In China, efforts are being directed at breeding tomatoes, pepper and aubergines resistant to sea water. By introducing key prolin synthesis enzymes, it is intended to make a wide range of plants resistant to high salt concentrations and drought. In Nigeria, work is going on with yams, cassava and sweet potato to improve their storage characteristics. In India, scientists have succeeded in halving the water consumption of mustard plants, and the corresponding field trials are currently in progress. Millet genes are being used to protect wheat and rice better against drought. Furthermore, transgenic variety of chickpea and pigeon pea which are resistant against drought and biotic stress are in the focus of research and should be on the market by 2005. In Iran, where drought and salinity are the main causes of reduced agricultural productivity, rice and some other crops are genetically modified to improve drought resistance and salt tolerance. In the Philippines, rice plants are being genetically modified at the International Rice Research Institute (IRRI) in order to achieve a drastic reduction in methane production. At the CIMMYT in Mexico, drought-resistant maize is being developed. At the USDA in the USA, efforts are being focused on drought-tolerant varieties of soybean. In the USA, research is being carried out in California to develop drought-resistant vine and fruit-tree varieties. In Egypt and the USA, wheat and tomato plants are being developed with resistance to salt and drought. In Japan, genes from barley are transferred into rice in order to grow rice in iron poor soil. In the USA, bent grass - a species used specially for golf courses - is being made drought-resistant. In Canada, trees are being developed with reduced sensitivity to frost and drought. In Spain, efforts are going on to make a wide range of plants resistant to drought, high salt concentrations and aridity. In South Africa, the main emphasis is on genetically modified plants able to survive drought. The Rockefeller Foundation presently concentrates its biotechnology programs in Asia on drought tolerance in rice and maize.

Drought causes severe yield loss worldwide, especially in developing countries, and it will continue to be among the most damaging stresses in crop production [4]. CNRS (National Centre for Scientific Research, Lyon, France), and INRA (Institute National de la Recherche Agronomoque, Lyon, France) in cooperation with Aventis CropScience proposed in 2001 a joint project under the MIR (French Ministry of International Relation) and the NRF (South African National Research Foundation) in order to improve crop tolerance to abiotic stress. The main objective is to engineer pathways to increase the basal level of essential amino acids and low molecular weight compounds in plants of agronomic interest.

Recent results of joint research conducted by Aventis CropScience and the Institute of Biotechnology of the University of Cambridge in England have shown accelerated plant growth resulting from increased cell division. After an *Arabidopsis* gene had been introduced into a tobacco plant, it was possible to achieve growth rates twice as high as those of normal plants. This achievement opens up opportunities to speed up the growing season, resulting in several harvests a year and an overall increase in plant biomass production [34].

In January 2002, Agrinomics LLC, a 50/50 research joint venture between Exelixis Plant Sciences and Aventis CropScience, characterized and catalogued more than 250,000 lines of the plant species Arabidopsis thaliana, and identified nearly its entire genome. The collection allows a rapid identification of genes which play important roles in crop improvement and which can enhance plant breeding. The complete sequencing of the *Arabidopsis thaliana* genome is a landmark in plant sciences and the beginning of a new venture to unravel genetic information and to gain better insight into the genetics of other species. Within the next five years, a broad spectrum of important functional genes will be found and used for significant crop improvements.

TECHNOLOGY TRANSFER

The adaptation of new technologies initially benefits the early adopters most, and since economies in a region are closely linked, technological changes in one country have an impact on neighbouring countries [22].

Efficient crop production, improved seeds and capacities for genetic engineering are of strategic relevance for nations and regions, and for the world as a whole.
Governments have to be encouraged to implement the supportive policies outlined by Krattinger [22]:

(i) to establish a coherent national biotechnology policy,
(ii) to provide incentives for R&D,
(iii) to ensure effective public awareness,
(iv) to establish effective biosafety and food safety regulations, and
(v) to enact IP (Intellectual Property) legislation to establish a regime consistent with legal obligations under WTO (World Trade Organization).

Policy makers must be both aware of their role and responsibility in biotechnology and know the support activities offered by professional organizations. In each country it will be essential to develop a specific biotechnology strategy in order to get access to benefits of modern biotechnology. A description of the status or necessary biotechnology policy in Mexico is given by Qaim and Falconi in 2001 [35].

Crop biotechnology policies adopted and actions undertaken by developing countries to implement crop biotechnology were developed for example, in Egypt and Kenya. These countries have developed biosafety procedures, regulatory frameworks and are enhancing biosafety expertise by training their scientists. Capacity-building programmes are key factors implementing crop biotechnology in developing countries [36].

Important aspects to enhance biosafety scientific expertise in sub-Saharan Africa are documented in the dialogue summary of the conference held in Grottaferrata, Italy, March 2002 [37]. Actual guidelines for biosafety systems in developing countries are filed by CABIO (Collaborative Agricultural Biotechnology) in May 2002 [38].

One of the major tasks of both the private and public sector is to provide suitable new and improved technologies. In doing this, ways must be found to enable components of technologies protected by patent to be used to a limited extent by public bodies, particularly in developing countries. The governments of developing countries, the donor community and the private sector must all take the steps that are so urgently needed to build partnerships [5].

Innovative and vigorous forms of public-private collaboration are required if the benefits of modern biotechnology are to be brought to all of the world's people; incentives are needed to encourage commercial research companies to share with the public sector more of their capacity for innovation [39].

To adapt private sector technology to the needs of developing countries, the following conditions must be fulfilled:

(i) a formal system of authorization to ensure that worldwide deregulation standards are met,

(ii) enforceable protection of intellectual property,
(iii) infrastructures for national and international technology transfer including analytical processes for GMO monitoring,
(iv) investments in development,
(v) a national or regional seed industry.

Actual aspects of the African seed industry were discussed during the AFSTA (African Seed Trade Association) congress in Dakar, Senegal, March 2002. A task for governments will be to fund public research institutions while simultaneously persuading the private sector - for example, industry - to enter into mutually advantageous partnerships.

According to the FAO (Food for All, FAO, 1996; Declaration of the World Food Summit, FAO, 2002) [40], cooperation in the transfer, adaptation and dissemination of technologies for food production in favour of the developing countries will be indispensable. The greatest challenge for the future will be to intensify the use of science and technology. Deeper scientific understanding simply means a systematic understanding of nature and this, together with the development, adaptation, dissemination and transfer of technologies including biotechnology, will permit sustainable development in agriculture. Principle 9 of AGENDA 21, Earth Summit in Rio de Janeiro in 1992, recommends the following: "Scientific understanding through exchanges of scientific and technological knowledge, diffusion and transfer of technologies, including new and innovative technologies" [34]

At the beginning of 2002, the UNCCD (United Nations Secretariat of the Convention to Combat Desertification) and Aventis CropScience signed a memorandum of understanding in the field of efficient use of natural resources, sustainable agricultural production, and technology transfer for a better crop protection and crop production, especially in arid regions of developing countries.

CONCLUSIONS

Enhancing agricultural efficiency and prudent conservation of resources by means of green biotechnology will be one of the answers to the questions raised at the beginning.

The industrialized and newly industrialized countries are ceaselessly developing new technologies and technical solutions. It will be decisive to implement these in good time and to enable the developing and least developed countries to avail themselves of them automatically. In this way it will be possible to prevent any fall-off in food production in the areas or regions at risk. The so-called First World has the resources to do this, together with the obligation to pass on the necessary knowledge and key technologies to developing countries. Ultimately this can only come about if all act together. Suggestions for future cooperative ventures are given in Partnerships in public and private agronomic research [5].

In this connection a catchphrase like *"More haste, less speed"* is totally inadequate. There is an ethical imperative not only to keep the technology portfolio open to biotechnology and genetic engineering, but also not to lose time. Everyday lost, every decision delayed, will kill people, increase poverty and will damage the environment, and put our future at risk. *"Be in time"* and "Let's act", or simply "Do it!" are what is required if we are to move on from a constructive dialogue to the necessary responsible action. Actions have to come from the Rio+10 conference 'Sustainable Development' in Johannesburg, South-Africa, September 2002. Let us work for that!

"Making New Technologies Work for Human Development" [1] will be a sustainable guideline for responsible people shaping our future, because: *"Mankind is at the crossroads".*

REFERENCES

1. **UN. Human Development Report 2001** Making New Technologies Work for Human Development. UNDP, New York, Oxford, Oxford University Press 2001.

2. **Kern M** Future of Agriculture. Global Dialogue EXPO 2000, The Role of the Village in the 21st Century: Crops, Jobs, and Livelihood, 15-17 August 2000, Hanover, Germany, 2000.

3. **Wiebe K, Ballender N and P Pinstrup-Andersen** Who will be fed in the 21st Century? John Hopkins University Press, USA, 2001.

4. **Kern M** Spannungsfeld: Ernährung, Landwirtschaft, Ökologie in der 1. bis 4. Welt - Lösungsansätze, Lösungsmöglichkeiten, Notwendigkeiten. in: Hohenheimer Umwelttagung 34: Globale Klimaerwärmung und Ernährungssicherung, eds: Böcker R und Sandhage-Hofmann. Stuttgart-Hohenheim. 2002;23-39.

5. **Kern M** New Partnerships, Partnership in Public and Private Sector. Agriculture and Rural Development, 2001;2:15-22

6. **Serageldin I and GI Persley** Promothean Science-Agricultural Biotechnology, the Environment and the Poor. CGIAR, Washington, USA, 2000.

7. **Pinstrup-Andersen P and Schiøler E Der Preis der Sattheit** - Gentechnisch veränderte Lebensmittel. Springer-Verlag, Wien, New York, 2001.

8. **Paarlberg RL** The Politics of Precaution, Genetically Modified Crops in Developing Countries. Food Policy Statement No. 35, International Food Policy Research Institute, Washington, USA, 2001.

9. **Thomson J** It's all in the genes. Sunday Times, 12 August 2001

10. **Mennessier MT** Biotechnology: A New Genetically Modified Strain is Changing Life For Small Farmers in Makhatini (South-Africa). Translation of an article appeared in Le Figaro, May, 2001.

11. **Fowler C, Smale M and S Gaiji** Unequal Exchange? Recent Transfers of Agricultural Resources and their Implications for Developing Countries. Development Policy Review, 2001;19/2:181-204.

12. **Qaim M** The Economic Effects of Genetically Modified Orphan Commodities: Projections for sweet potato in Kenya. ISAAA Briefs, 13, published in collaboration with Centre for Development Research (ZEF), Bonn, 1999.

13. **Asian Development Bank.** Agricultural Biotechnology, Poverty Reduction, and Food Security. A Working Paper, ADB, Manila, The Philippines, 2001.

14. **Wambugu F** Case Study: North-South-Transfer of Biotechnology to East Africa. In: International Workshop on Biotechnology for Crop Production - its Potential for Developing Countries. Berlin, 9-13 December 1996.

15. **James C** Global Review of Commercialised Transgenic Crops: 2001. ISAA Briefs

16. **Perseley GJ and MM Lantin** (eds) Agricultural Biotechnology and the Poor. CGIAR, Washington, USA, 2000.

17. **Spillane C** Could agricultural biotechnology contribute to poverty alleviation? AgBiotechNet, Vol. 2, March 2000.

18. **Phipps RH and DE Beever** New Technology: Issues relating to the use of genetically modified crops. J. Animal and Feed Sciences, 2000;9:543-561.

19. **Amerasinghe N** Poverty, Food Security, and Agricultural Biotechnology: Challenges and Opportunities, Seventh International Forum on Asian Perspectives June 18-19, 2001, Paris, France.

20. **Pachio D, Escobar Z, Rivas L, Gottret V and S Perez** Income and employment of transgenic herbicide resistant cassava in Colombia: A preliminary simulation. In: The International Consortium on Agricultural Biotechnology Research (ICABR), 2001.

21. **Pinstrup-Andersen P** Developing Appropriate Biotechnology Policies for Developing- Country Agriculture. In: The Unfinished Agenda, Perspectives on Overcoming Hunger, Poverty, and Environmental Degradation. Pinstrup-Andersen P and Pandya-Lorch R, (eds). International Food Policy Research Institute, Washington, USA, 2001.

22. **Krattinger AF** Public-Private Partnerships for Efficient Proprietary Biotech Management and Transfer and Increased Private Sector Investments. A Briefings Paper with Six Proposals Commissioned by UNIDO. IP Strategy Today, 2002;4:1-42, **www.swiftt.Cornell.edu**

23. **USDA Economic Service:** Meeting World Food Demand, The Role of Biotechnology. Economic Issues in Agricultural Biotechnology, 2001;AIB-762:47-52.

24. **Sehgal S** Agricultural Biotechnology and Seed Industry: Some Implications for Food Production and Security: in: Agricultural Biotechnology in Developing Countries: Towards Optimising the Benefits for the Poor. Qaim M, Krattinger A and von Braun J (eds), Kiuwer Academic Publishers, 2000.

25. **Huang J, Rozelle S and Q Wang** Plant Biotechnology in China. Science 2002;295:671-677

26. **Zhang Q** Agricultural Biotechnology, Opportunities to Meet the Challenges of Food Production. In: Perseley GJ and Lantin MM (eds.) Agricultural Biotechnology and the Poor. CGIAR, Washington, USA, 2000.

27. **De Kathen A** Transgenic Crops in Developing Countries - A report on field releases, biosafety regulations and environmental impact assessments. Umweltbundesamt Texte, Berlin, 1999;58

28. **Carpenter JE and LP Gianassi** Agricultural Biotechnology: Updated Benefit Estimates. National Center for Food and Agricultural Policy, Washington, 2001;1-46.

29. **Edge JM, Benedict JH, Carroll JP and HK Reding** Bollgard Cotton: An Assessment of Global Economic, Environmental, and Social Benefits. J. Cotton Science, 2001;5:1-8.

30. **Phipps RH and JR Park** Environmental benefits of genetically modified crops: Global and European perspectives on their ability to reduce pesticide use. J. Animal and Feed Sciences, 2002;11:1-18.

31. **FAO** Twenty-sixth FAO Regional Conference for the Near-East, Biotechnology for Agriculture, Forestry and Fisheries in the Near-East Region, Tehran, Islamic Republic of Iran, 9-13 March, 2002.

32. **Cohen JI** Harnessing Biotechnology for the Poor: Challenges ahead for Capacity, Safety and Public Investment. J. Human Development, 2001;2/2:239-263.

33. **Mahalakshmi V and R Ortiz** Plant genomics and agriculture: From model organisms to crops, the role of data mining for gene discovery. EJB Electronic Journal of Biotechnology, 2001;4/3:1-10.

34. **Kern M** 'Visualised Agenda 21' - Poster-Session made by Aventis CropScience, Manfred Kern/Konzept+Design, Frankfurt, 2001.

35. **Qaim M and CA Falconi** Agricultural biotechnology policies and research investments in Mexico. Int. J. Biotechnology, 2001;3, 3/4:323-337.

36. **DaSilva EJ, Baydon E and A Badran** Biotechnology and the developing world. Electronic Journal of Biotechnology, 2002;5/1, **http://www.ejb.org/content/vol5/issue1/full/1**

37. **Meridian Institute** Enhancing biosafety scientific expertise in Sub-Saharan Africa, Dialogue summary, Grottaferra, Italy, 12-14 March 2002. **http://www.merid.org/biosafety/Meeting_Summary.pdf**

38. **USAID Guidelines.** 2002 Program for Biosafety Systems (PBS). **http://www.usaid.gov/ftp_data/pub/OP/RFA/rfaegatafs02001/rfaegatafs02001.pdf**

39. **Royal Society of London**, the U.S. National Academy of Sciences, the Brazilian Academy of Sciences, the Chinese Academy of Sciences, the Indian National Science Academy, the Mexican Academy of Sciences and the Third World Academy of Sciences: Transgenic Plants and World Agriculture, National Academic Press, Washington, USA, 2000, **http://www.nap.edu/html/transgenic**

40. **FAO.** Declaration of the World Food Summit: five years later, World Food Summit, FAO, Rome, Italy, 10-13 June, 2002. **http://www.fao.org/DOCREP/MEETING/004/Y6948E.HTM**