Katholieke Universiteit Leuven
Faculty of Agricultural and Applied Biological Sciences

Working Paper
2002 / 73

BIOTECHNOLOGY IN THE SOUTH: ABSOLUTE NECESSITY OR ILLUSION?

Eric TOLLENS

December 2002

This paper (pdf) can be downloaded following the link:
http://www.agr.kuleuven.ac.be/aee/clo/wp/tollens2002i.pdf

With thanks to Matty Demont and Profs. J. Vanderleyden and R. Swennen for their constructive comments on a first draft.

Department of Agricultural and Environmental Economics
K.U.Leuven
Willem de Croylaan 42, B-3001 Leuven – Belgium
Tel. +32-16-321614, Fax +32-16-321996

Tollens, E. "Biotechnology in the South: Absolute Necessity of Illusion?" Working Paper, n° 73, Department of Agricultural and Environmental Economics, Katholieke Universiteit Leuven, 2002.

This paper has been presented at the
Interdisciplinary Course 'Development and Cultures', Academic Year 2002-2003,
Leuven, December 17, 2002.

Prof. Eric Tollens,
Katholieke Universiteit Leuven, Leuven, Belgium
de Croylaan 42, B-3001 Leuven (Heverlee), Belgium
Tel.: +32 16 32 16 16, Fax: +32 16 32 19 96,
Email: eric.tollens@agr.kuleuven.ac.be

The EUWAB-project (European Union Welfare Effects of Agricultural Biotechnology)
http://www.agr.kuleuven.ac.be/aee/clo/euwab.htm

Since 1995, genetically modified organisms have been introduced commercially into US agriculture. These innovations are developed and commercialised by a handful of vertically coordinated "life science" firms who have fundamentally altered the structure of the seed industry. Enforcement of intellectual property rights for biological innovations has been the major incentive for a concentration tendency in the upstream sector. Due to their monopoly power, these firms are capable of charging a "monopoly rent", extracting a part of the total social welfare. In the US, the first *ex post* welfare studies reveal that farmers and input suppliers are receiving the largest part of the benefits. However, up to now no parallel *ex ante* study has been published for the European Union. Hence, the EUWAB-project (European Union Welfare effects of Agricultural Biotechnology) aims at calculating the total benefits of selected agricultural biotechnology innovations in the EU and their distribution among member countries, producers, processors, consumers, input suppliers and government. This project (VIB/TA-OP/98-07) is financed by the VIB - Flanders Interuniversitary Institute for Biotechnology, in the framework of its Technology Assessment Programme. VIB is an autonomous biotech research institute, founded in 1995 by the Government of Flanders. It combines 9 university departments and 5 associated laboratories. More than 750 researchers and technicians are active within various areas of biotech research. VIB has three major objectives: to perform high quality research, to validate research results and technology and to stimulate a well-structured social dialogue on biotechnology. Address: VIB vzw, Rijvisschestraat 120, B-9052 Gent, Belgium, tel: +32 9 244 66 11, fax: +32 9 244 66 10, www.vib.be

Table of Contents

1. Introduction

Agricultural production almost needs to double in the 21st century (Evans, 1998). Not only is the population expected to increase by half, i.e. from 6 billion in 2000 to about 9 billion by 2100, or even more, but also meat and animal protein consumption per capita is expected to increase by half in developing countries. This requires a drastic increase in cereal and legume production which is the basis of animal protein production (Tollens, 2002), (Ballenger et al., 2001), (Delgado et al, 1999), (Mc Calla et al., 2001), (UNFPA, 2001).

By 2100, it is expected that the world population will have stabilized or nearly so, and that the demographic transition will have run its full course. There is still a lot of debate whether the population will stabilize at 8,5, 9 or 10 billion, also depending on the unforeseeable impact of AIDS. The increase in meat and animal protein consumption is fueled by higher per capita incomes, and a universal desire to diversify the diet and eat meat, dairy products, eggs and fish (more and more from aquaculture) when income allows. This phenomenon is now witnessed in China where consumption of animal protein has doubled over the last two decades and is still growing. China is already the largest pig producer in the world and India, known for its large vegetarian population, has become the largest milk producer of the world in the 1990's (Tollens, 1999).

All this puts tremendous pressure on agricultural resources and opens the specter of Malthusian doomsday (Malthus, 1966), with large scale famines, and wars fueled by the pursuit of agricultural land and/or water for irrigation. The ultimate test of Malthus' prophesy is due in the 21st century, but most agricultural scientists are confident that the world's population can be adequately fed. The only condition is that agriculture, more than before, is based on science and technology, with agricultural intensification as the only route to meet mankind's food and fiber needs. This implies that agricultural resources must be used in a sound, sustainable way, that yields per unit of land or per animal must increase (drastically in developing countries), and become more stable and less subject to biotic and abiotic stresses. This will require the best available technology, and agricultural scientists will quickly add that biotechnology is the best available technology, amongst others, to meet the high yield requirements. In what follows it will be pointed out that we are only at the start of the biotechnology revolution!

If only food production needs to follow pace with population growth, a 50% increase is required. However this would leave the food insecure population of today, estimated at roughly 800 million (FAO, 2001), untouched, which is a highly unacceptable situation. Most of the increase in food production is needed in the South, as over 90% of world population increase will take place there, and food insecurity is mainly located in the poor countries of the South, particularly in South Asia and sub-Saharan Africa (Christiaensen et al., 1995), (Tollens, 1998).

Growth rates of yields have slowed during the period 1987-2001. Soil erosion, declining soil fertility in tropical countries, pests and diseases, water shortages, etc. have contributed to pressures on the environment and resource base. Thus, the 21st century needs another green revolution to elevate global food production (Conway, 1999). And this green revolution needs to be doubly green (yield increase, enhancement of the environment), implying biological technology (non chemical).

2. Biotechnology and other agricultural technologies

There is wide agreement that most of the food production increase has to come from agricultural intensification (Boserup, 1965 and 1981). The land frontier in most countries is closed, and taking more land into production would either require marginal lands to be brought under cultivation, or infringe on nature reserves, wetlands, rainforest or other areas of high biodiversity and ecological value. This does not exclude that in certain parts of Latin America or sub-Saharan Africa, new land can be brought under production, as occurred in the 20th century. But for most, this is not the preferred option. Thus, most of the increase in food production must come from further agricultural intensification in the South (IFAD, 2001). This will result in higher yields and/or more stable yields, and will require more externally procured inputs such as improved seeds, organic and inorganic fertilizers, pesticides, mechanization and associated agricultural credit to pay for these inputs. Also, irrigation needs to increase drastically, particularly in sub-Saharan Africa and Latin America, as Asia has already exhausted most of its irrigation resources. But irrigation is an expensive technology, requiring an average investment of about 10,000 Euro per ha. And management of irrigation schemes poses many problems, as there are many sustainability failures in irrigated agriculture, in particular increasing salinity of soils.

It is usually the combination of improved technologies which, through synergistic effects, produce the highest pay-offs and yield increases. Thus, improved, high yielding seeds need to go together with improved (integrated) soil fertility management, integrated pest management, adequate post-harvest care, and improved marketing to really result in quantum jumps in productivity and incomes. This was the case in the green revolution in Asia, which only took place in irrigated agriculture, on the best soils, and only for two crops: rice and wheat.

Thus, biotechnology[1] by itself, which will confer genetic superiority to a crop, will never be sufficient to solve food production problems on its own. It must be part of an improved farming system, where the other required agricultural inputs and management practices are favorable for the genetic potential to be realized. Biotechnology in isolation will not solve the food problems and will not necessarily contribute to poverty alleviation. One has to look at the whole farming system and the whole livelihood, including input distribution and agricultural marketing and non-farm income. But the attraction of biotechnology stems from the fact that you can wrap the technology in the seed thus facilitating integration into traditional smallholder farming systems (Qaim et al., 2000). Moreover, you can alter the genetic potential of crops as never before, usually cheaper, much quicker and in a much more focused way. This is elaborated hereafter.

3. The strengths of biotechnology

With biotechnology, you can do things faster and cheaper and you can do things which you cannot do otherwise. This is particularly important for characteristics (traits) which depend on only one gene[2]. Inserting this gene, wherever it comes from,

---

[1] With biotechnology, we mean modern biotechnology or molecular biotechnology, involving genetic engineering and the creation of transgenic plants. In our definition, beer brewing or in vitro culture is not included.

[2] In the meantime, 12 genes together can now already be transferred thus conferring several characteristics together in the target plant.

in the genome of your target plant may confer that characteristic to that plant. Gene expression is either constitutive expression, which always occurs, or inducible expression, which happens only under certain conditions. Thus, with genetic engineering you can break the crossing barrier between species. Even within the same species, instead of mixing the genome of two different plants, through breeding, and having to back cross several times in order to get rid of the unfavorable traits, you can now insert the desired gene for the particular trait into the plant. In reality, it is not as easy as described above. Identifying the desired genes, gene cloning and inserting them in the right place (genetic engineering) is not that easy. And even when they are there, they must express themselves. A lot of trial and error, and in some cases luck is involved. With genetic engineering, thousands of new plants can be made by trial and error in a routine matter on a micro-scale (in one cell). And molecular technologies allow a quick identification of the desirable plants (cells), e.g. through antibiotic resistance or coloring, such that not all plants (cells) need to be grown into full plants. Thus, a lot of progress has already been made.

Unfortunately, the most important characteristics such as yield characteristics, or plant architecture, or the ability to fix nitrogen from the air through symbiosis with bacteria, depend on several genes, located on different chromosomes in the genome. It is not yet possible to transfer them all to one particular plant and make sure they are in the right place and express themselves. In this respect the production of the Golden Rice (which is much debated) is a breakthrough from the scientific side because it illustrates that complex biochemical pathways can be made to express in new plants, despite that many different genes are involved. All genetically modified (GMO) crops so far in use have only one "foreign" gene inserted for one particular characteristic, such as tolerance to a particular herbicide, or for producing an insect toxin (Bacillus thuringiensis or Bt). The useful crops with two foreign useful genes ("stacked genes"), such as herbicide tolerance and insect resistance (Bt) are just now coming onto the market. Work is on-going to induce useful traits, e.g. nutritional value, which depend on several genes. But almost all GMO crops presently grown commercially have either:

- a gene for insect resistance (Bt), or
- a gene for herbicide tolerance

Insect resistance is particularly important for insects which are difficult to kill with insecticides because they hide inside the plant, such as the European corn borer, which is a stem borer in maize and is important in southern Europe (Spain) or in the U.S.A.. Another example is the cotton bollworm borer, which eats inside cotton bolls, and cannot be killed easily by contact insecticides. Systemic insecticides are needed which circulate throughout the plant, and which are usually quite toxic, also for humans. The Bt-insecticide, which kills these larvae from butterflies, is a protein which is naturally found in Bt-bacteria which are common in soils. For cotton, which is usually sprayed 5-10 times against the bollworm and other insects, insect resistance represents a tremendous achievement, as only one spraying (against the other insects) is needed. Without frequent spraying against the bollworm in a normal cotton field, the whole cotton harvest is usually lost.

Herbicide tolerance allows total weed control by spraying once or maximum twice with the total herbicide (Roundup, Basta, …) which kills all plants except the GMO plant. And weed control is one of the major headaches of farmers, as there are so many types of weeds, and with weeds, yields are depressed. Thus, herbicide tolerance allows effective weed control in one or two passes only, against 3-5 otherwise, flexibility in application (it does not matter when you spray) and total effectiveness, resulting in somewhat higher yields.

Present GMO varieties now being released commercially also have resistance against fungi or viruses, but this is much less established and remains to be confirmed under field conditions.

Other GMO-activities concern drought tolerance, cold tolerance, salt tolerance, increased nutrient content, e.g. golden rice which contains more precursors vitamin A, etc.. In fact, the list is endless but much is still in the pipeline and not yet commercially proven.

In principle, almost anything is possible although in practice, it requires large investments, long time lags (at least 5-10 years) and sometimes uncertain effectiveness.

4. The dangers of biotechnology

As with all new technologies, there are risks and dangers (Driesen et al., 1994), (Oxfam, 1999) although many of them have not (yet) realized and remain hypothetical. They can be summarized as follows:

- risk of genetic pollution, i.e. proliferation of particular genes into the environment, conferring unwanted superior characteristics to weeds ("super weeds") or contamination of origin gene pools (e.g. maize and theosinte in Mexico) by foreign genes. This risk is particularly important for cross-pollinating crops (as against self-pollinating crops) and in regions of origin of cultivated plants where many wild relatives exist;

- risk of losing bio-diversity as more and more farmers grow the same "superior" GMO varieties. This was also the fear with the green revolution;
- risk of allergy or toxicity for humans and animals. There are many toxic plants existing in nature and many people are susceptible to allergy. Introducing foreign genes in cultivated plants or domestic animals carries the risk of unwanted side-effects such as allergy. But GMO foods and food products do not inherently present any more unintended toxic properties than those presented by conventional breeding practices. Crops modified by modern molecular and cellular methods do not pose risks different from earlier methods. There is no need for a fundamental change in established principles of food safety to evaluate GMO food, nor is a different standard of safety required. While the use of newer biotechnologies broadens the scope of genetic changes that can be made in food organisms and the scope of possible food sources, this does not inherently lead to foods that are less safe than those developed by conventional techniques (Crop Biotech Update, October 25, 2002), (Lomborg, 2001);
- ethical problems: transfer of genes between species and even from plants to animals (and humans) and vice versa can be seen as unethical by some ("playing God-tampering with nature"). Certainly transfer of human genes into plants or animals is seen by most as unethical;

- over dependence of farmers on seed companies and chemical companies; dominated by large multinational enterprises[3]. There are only a handful large, multinational chemical-seed companies which venture into GMO's (Monsanto, Dupont, Syngenta, Novartis, Dow). The technology which they use is protected under strict patents. For particular genes or traits, they possess virtual monopoly power. Once farmers are "hooked" on their technology, they can extract high monopoly rents. When farmers buy GMO-technologies from these companies (seed + chemicals + instructions), they have to sign a contract, which forces them to pay a technology fee, not to reuse or sell the seed and observe a refuge area with conventional seed (to reduce the risk of resistance development). Some criticists talk about total loss of farmer sovereignty over their seeds and planting material;
- loss of foreign markets: because of the moratorium on GMO plants in the European Union since 1998, transgenic seeds for human use (corn, soybeans, canola) are not allowed in imports. They are still allowed for industrial use or in animal feed, but this is bound to change too. EU-legislation on GMO's not only requires labeling and separate processing. Even if no DNA can be detected in the final product for human consumption, if the process involves GMO-DNA, that would ban its use for human consumption (e.g. in sugar or vegetable oils, which contain no DNA). Thus, the USA, Argentina, South Africa, China and other countries growing GMO-crops on a large scale cannot export GMO-crops destined

[3] The rather negative attitude towards GMO's is partly the fault of multinational life science companies, which in the early days of biotechnology "imposed" their technology rather than offered them to "takers" like any other technology, and governments, particularly in Europe, which developed much too late accompanying policies and a regulatory framework. The same risk exists now in developing countries.

for human consumption in the EU. A 1% threshold is allowed and segregation and identity preservation is required in the processing of crops which may contain GMO's. This represents an additional cost for exporting countries which also grow GMO-crops[4];

- greater dependence of the South on the North for their seed supply and technology. As most of the transgenic technology is developed in the North, and is protected by patents, countries in the South become more dependent on goodwill and contracts with the North. But one has to realize that this is already the case with many technologies or products: drugs, mining technology, oil industry technology, medical technology, machinery, etc.. The only solution is to develop home-grown technology and invest in science and technology and develop scientific capacity through universities and research institutions. Only a few, especially large, developing countries follow this strategy.

5. The spread of GMO-crops in the world

GMO-crops are grown commercially since 1995. The first countries where they were planted were the USA and Argentina. Nowadays, many countries have GMO-crops. Argentina has the highest % of any country, followed by the USA. There are now an estimated 45 million hectares of GMO-crops all produced by commercial producers from commercially sold seeds. 76% in industrial countries and 24% in developing countries (see appendix tables 1-5). Almost all the new genes in commercially grown

[4] Brazil does not allow GMO-crops but it is estimated that about 20% of its production contains GMO's, from seeds smuggled from Argentina which has the highest % of GMO's in its agriculture in the world.

GMO crop were produced by Monsanto, a large multinational life science company (Jikun Huang et al., 2002). In Japan, 43 varieties of 6 GMO crops are approved for production and human consumption but not much is grown yet. In Europe, 14 transgenic crops are approved for cultivation and use, including tobacco, rape, soybean, chicory, maize and carnation. As of March 2001, 14 other transgenic crops were pending approval (Clive James, 2001).

Spain has about 20.000 ha of GMO-corn (Bt), with varieties accepted before the EU-wide moratorium took effect in 1998.

The country where the GMO-spread is now the most rapid is China (Jiking Huang et al., 2002). An estimated 1.5 to 2 million ha of Bt-cotton is grown (over 30% of the cotton area) and the hectarage under GMO-crop is spreading rapidly. The average Bt-cotton farmer in China has reduced pesticide sprayings for the Asian boll worm from 20 times for conventional varieties to 6 times per year and produces a kilogram of cotton for 28% less cost than the farmer using non-Bt-varieties (see appendix table 6). China now spends about 100 million US$ per year on GMO-research, on about 20 different types of crops, as much as all other developing countries together[5]. Within five years, it is expected that the Chinese government may spend over 500 million US$ on transgenics. And in China, it is research funded by the Government, not by private (multinational) companies, which counts! Foreign multinational companies (Monsanto) are paid for technology transfer and services, but most of the varieties are developed and owned by the Biotechnology Research

[5] In particular China invests at high speed in genomics projects, e.g. they have sequenced the rice genome; they are field testing cold tolerant tomato.

Institute of China within the Chinese Academy of Agricultural Sciences. Some private Chinese companies are also involved, but in collaboration with the State. China is even planning to sell its technology to other countries, such as India (and that worries multinational companies). China has thus embarked on an agricultural strategy based on the development and spread of transgenic crops. Other developing countries where GMO-technology is applied and where GMO-crops are grown are:

- Egypt: especially for Bt-cotton and corn AGERI, a state research station devoted to plant biotechnology, is developing new transgenics, in partnership with Monsanto and Dupont, financed by USAID and the Egyptian government. They are also testing salt tolerant wheat;
- South Africa: Bt-cotton is grown in South Africa by both large-scale and small-scale farmers and between 10-15% of maize grown is GMO, and the Agricultural Research Council is investing in plant biotechnology. Other transgenic crops will soon be grown. South Africa is leading the way in growing GMO subsistence crop with the production of GMO white maize in 2002 (Njobe-Mbuli, 2000);
- Kenya: with the aid of Monsanto, KARI (Kenya Agricultural Research Institute) is developing transgenic sweet potatoes with virus resistance. Also, Bt-maize is in the final stages of testing;
- Mexico: GMO cotton and corn, imported from the USA. They are also testing transgenic bananas with reduced ripening characteristics;
- Zimbabwe: transgenic research is on-going;
- Bolivia: are testing frost tolerant potato;
- Thailand: are testing salt tolerant rice and drought tolerant rice;

- India: a large biotechnology research effort is underway but no GMO releases yet except Mahyco-Monsanto Bt-cotton in 2002. India is also testing moisture tolerant cabbages;
- Nigeria: the Federal Government has announced a 10 million US$ program in plant biotechnology. The legal framework for biosafety regulation and testing of transgenic crops is now in place. IITA (International Institute of Tropical Agriculture) based at Ibadan has a biotechnology program on several crops: cowpea, bananas and plantains;
- Costa Rica: is testing transgenic bananas with reduced ripening characteristics.

In total, about 13 million hectares in developing countries (including Argentina, Mexico, etc.) are in GMO crops, about one-third of that in developed countries. Adoption in developing countries is almost exclusively by commercial large-scale producers, except for Bt-cotton in China, Mexico and South Africa.

Most of the CGIAR (Consultative Group on International Agricultural Research) 16 Institutes are involved in biotechnology research. Molecular markers and probes are already used extensively in classical plant breeding. In fact, present progress in traditional plant breeding is greatly enhanced by these new diagnostic tools developed with gene technology. Amongst the CGIAR-centers, those most heavily involved are:

- CIMYT (Mexico): wheat and corn
- IRRI (Philippines): rice
- CIAT (Columbia): cassava, beans
- CIP (Peru): potatoes

It is to be remarked that for developing countries, except for the real big and potential powerful ones (China, India, Brazil), multinational companies show little or no interest, as their patent protection in these countries is weak and because they cannot expect to make money on their efforts there. When they are involved, it is because a third party, governments or aid agencies (particularly USAID) or both combined pay them for the technology transfer and capacity development. The risk that multinationals will control the seed chain and the farmer's right to their own seeds in these countries is purely theoretical. On the other hand, the risk that these companies seek patent rights on useful traits in landraces in these countries is real, e.g. the patent on Basmati rice traits awarded to a company from Texas, or the patent on the neem gene, originally from India. Moreover, multinational companies are really only interested in the most important crops grown also in industrialized countries, such as wheat, corn, rice, cotton, canola. They are not at all interested in cassava, sweet potatoes, millet, plantains, etc. which are only grown in poor developing countries. In many cases, proprietary technology is meaningless as most of these "orphan crops" are propagated vegetatively, and not through seeds, e.g. cassava through cassava cuttings, plantains through suckers, etc.

One can conclude that for developing countries, the state and aid agencies need to take the lead to get multinational companies (and their technology) involved. And the state needs to determine the terms and conditions under which multinational companies can cooperate, as is the case in China.

6. The case for developing countries

What is most lacking in developing countries is the capacity to do their own biotechnology research and development, and the legal framework for biosafety testing, patent enforcement and release of transgenic crops. Countries introducing GMO-planting material need to have a biosafety control system for the testing under laboratory conditions and confinement facilities. They need to be able to test for toxicity, allergic properties, and spread of pollen in the wild and potential cross-breeding. They need to be able to enforce international treaties on plant variety diffusion, biodiversity and international property rights (UPOV, TRIPS, Cartagena protocol, WTO). Biosafety is thus emerging as the principal constraint on release of GMO plants in developing countries (Paarlberg, 2000 and 2001). Most developing countries, except for the big ones, are very weak in these regulatory matters. In most cases, they have no scientific knowledge to be able to judge on their own whether to get involved or not. Many think that because there is a moratorium in Europe, there must be something wrong with the technology. What is thus most needed is training and capacity development in this area, and unbiased, neutral information. Collaboration on plant biotechnology is not possible if the receiving partner cannot make up his own judgment and decide independently.

Biotechnology, i.e. development of transgenic plants, has tremendous potential for developing countries to meet tomorrows food needs, and to be competitive in agriculture in the world market (Pardey, 2001). It is thus not surprising that an agricultural giant such as Brazil now spends 350 million US$ per year on agricultural research through its agricultural research institution Embrapa. Unfortunately, most of it is spent on export crops such as corn, soybeans, citrus, coffee, not on crops which matter for the poor in the North-East (cassava, beans, groundnuts, sorghum).

The potential in biotechnology is not so much in yield enhancement, but in more stable yields through pest control (virus-, bacterial-, fungal diseases, insect attacks, weed control) and added robustness to plants. Also, tolerance to abiotic stresses such as drought, salinity, extreme temperatures (hot, cold) etc. can be tackled through resistance or tolerance genes which confer these desirable traits. Cropping in adverse conditions and marginal lands could benefit greatly from biotechnology advances catered to these conditions. Also, nutritional enhancement of crops, especially for micronutrients (vitamins, minerals), through biotechnology offers potential. Golden rice, with enhanced vit. A content, is the best example here. In animal production, apart from diagnostic tools, better resistance to animal diseases, better forage conversion, and improved forage and feed resources through biotechnology offer the best scope for progress. But as said before, biotechnology is not a golden bullet or once-for-all solution. It can be a very useful enhancement in agriculture which must necessarily be based more and more on science and technology. For some pest problems, such as insect attacks (stem borers, bollworms), or weed control, it is simply the best technology available, with tremendous savings in pesticides which are not needed anymore. In some cases, the environment may even be the greatest winner, by reducing chemical pollution and by saving rainforest, wetlands and fragile lands from agricultural conversion.

China is a good example of a (still poor) developing country which is embarking on a bold mission to harness biotechnology for its own food and fiber needs in the future.

Nobody today in China is starving from hunger or malnutrition and they want to keep it that way. Rapid industrial development, particularly on the eastern seaboard, needs to go hand in hand with rapid agricultural development in the interior where still over 50% of the population is at work in agriculture and related industries. They have figured that agricultural biotechnology is the way to go, with 100 million US$ per year and over 5,000 scientists involved, all over China, working on about 20 crops. Bt-cotton in China is a shining success and they see no reason why not to extend this technology to other crops. Is China the model?

7. Conclusions

Biotechnology for agriculture in the South is not the golden bullet nor an absolute necessity. But it is the best available technology for solving certain problems. Its greatest potential is in stabilizing yields at high levels by alleviating biotic and abiotic stresses. What biotechnology can do is best illustrated by the case of Bt-cotton in China. It represents tremendous savings in terms of less insecticide use, higher yields and incomes, less toxicity for humans, less risk overall. And farmers benefit greatly. Even in industrialized countries, about two-thirds of the advantages go to farmers, plus added flexibility, while one-third goes to the multinational companies. Unfortunately, consumers so far gain little if any, except through less use of pesticides/use of less toxic pesticides. The next generation of transgenic crops is expected to have definite consumer advantages in terms of better nutritional value or other positive characteristics.

What is lacking most in the South is the capacity to develop their own biotechnology applications, and to implement biosafety regulations and -testing. Even the international agreements and -protocols of significance in this area are not much more than dead letter for most developing countries. It is clear that they will need collaboration and support from the North on this. There is so much misunderstanding and fiction on this matter, and the real drama is that the potential advantages and benefits are lost or poorly understood by most in the South. There is so much emphasis and focus on the risks and dangers, which are a luxury for most poor developing countries anyway, that the big picture of the potential gains is lost. The misguided focus on the potential dangers of transgenic corn from the USA as food aid in Zambia and Zimbabwe, where thousands of people were on the brink of starving from hunger, is a testimony to the misbelieves and wrong perceptions which so many people have of biotechnology. For over 5 years, Americans, Canadians and others have been consuming large quantities of food prepared with GMO crops and not one case of sickness, let alone dying, has been reported by the alert media.

In the medical field, one-third of our medicines are now derived from biotechnology applications, including insulin for diabetes patients, most of our antibiotics, hormones for therapy, etc.. To cure somebody, biotechnology is O.K. and is not questioned, to keep somebody alive (by eating), it could be dangerous! This, at least, is what the opponents of biotechnology think. It is time that we trust science and technology based on science, and focus on the big issues. For most poor countries in the South, this means alleviating poverty and food insecurity, and planning for the population increase which is bound to come in this century. Technology is one of the most powerful tools we have to achieve the goals of food security and poverty alleviation. Transgenic crops can help to ensure that an adequate food supply is available, and in the process of producing it, millions of poor farmers can make a living and may be lifted out of poverty. Of the 800 million poor and food insecure in this world, 70% lives in rural areas and finds its livelihood rooted in agriculture. Biotechnology can help to increase their productivity and incomes. This chance should not be lost (Per Pinstrup-Anderson, 2001).

But help will be needed from the North to build-up a biotechnology-capacity in the South, including biosafety regulations and protocols. And most of the investments in the technology will have to be made by the public sector as new plant varieties and seeds are still mainly a public good in most countries. Multinational companies cannot be expected to help, on a large scale, in developing countries except if they are paid for technology transfer and capacity building. There are only a few large, technology-developing poor countries where multinationals have a genuine interest and where large private seed companies are already operating. For the real "orphan" crops, the multinationals will probably never show interest, except for public relations purposes only. Thus governments from the North and the South need to enter into genuine partnerships to build up biotechnology capacity in the South and to tap the potential benefits of this technology for the poor and hungry of today and particularly tomorrow. Moreover, low-income people and countries should be empowered to make their own choices based on informed debate and their own risk-benefit calculation (Per Pinstrup-Anderson et al., 2002). Differential environmental concerns between rich and poor countries are likely to lead to different perspectives on the use of modern biotechnology.

References

- Ballenger, N., Pinstrup-Andersen, P. & Wiebe, K., 2001, Who will be fed in the 21st century?, IFPRI, Washington, D.C., John Hopkins University Press, 89 p..
- Boserup, E., 1965, The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure, Aldine Publishing Co., Chicago.
- Boserup, E., 1981, Population and Technological Change: A Study of Long-Term Trends, The University of Chicago Press, Chicago.
- Christiaensen, Luc and E. Tollens, 1995, Food Security: From Concept to Action - a Status Quaestionis, K.U.Leuven and ABOS, 129 p. (ook in het Nederlands beschikbaar).
- Conway, G., 1999, The doubly green revolution: Food for all in the 21st century, London, Penguin.
- Crop Biotechnology Update, Newsletter, October 25, 2002, Global Knowledge Center on Crop Biotechnology, international Service for the Acquisition of Agri-biotech Applications (ISAAA) and Ag. Biotech Net, www.ISAAA.org/kc.
- Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S. and Courbois, C., 1999, Livestock to 2020, The Next Food Revolution, IFPRI-FAO-ILRI, Washington, Rome, Nairobi.
- Driesen, Liliane en Hannelore Beerlandt, 1994, Biotechnologie en duurzame landbouw, Universitaire Pers Leuven, Leuven, 211 p.
- Evans, L.T., 1998, Feeding the ten billion: plants and population growth, Cambridge University Press, Cambridge, 247 p.
- FAO, 2001, Food insecurity: when people live with hunger and fear starvation, The State of Food Insecurity in the World, Rome.
- FAO, FAOSTAT database: http://faostat.fao.org, Rome.

- IFAD, 2001, Rural Poverty Report 2001, Rome.
- James, Clive, 2001, Global Review of Commercialized Transgenic Crops: 2000, ISAAA Briefs No 23, Ithaca, N.Y..
- Jikun, Huang, Scott, Rozelle, Carl, Pray, Qinfang, Wang, 25 January 2002, Plant Biotechnology in China, Science, Vol. 295, pp. 674-677.
- Jikung, Huang, Carl, Pray & Scott Rozelle, 8 August 2002, Enhancing the Crops to Feed the Poor, Nature, Vol. 418, pp. 678-684.
- Lomborg, Bjørn, 2001, The Sceptical Environmentalist; Measuring the Real State of the World, Cambridge University Press.
- Malthus, Thomas Robert, 1966, First Essay on Population, Mac Millan, London.
- Matim, Qaim, Detlef, Virchow, 2000, The Role of Biotechnology for Global Food Security, Agrarwirtschaft 49, pp. 348-356.
- McCalla, A.F. and C.L. Revodero, October 2001, Prospects for Global Food Security, A Critical Appraisal for Past Projections and Predictions, IFPRI, Discussion paper 35, Washington, D.C..
- National Academy Press, July 2000, Transgenic Plants and World Agriculture, Washington, D.C., 46 p..
- Njobe-Mbuli, B., 2000, South Africa: Biotechnology for Innovation and Development, in G.J. Persley and M.M. Lantin, (eds.), Agricultural Biotechnology and the Poor, Washington, Consultative Group on International Agricultural Research, pp. 115-117.
- Oxfam Great Britain, 1999, Genetically Modified Crops, World Trade and Food Security, accessible at http://www.oxfam.org.uk/policy/papers/gmcrop.htm.
- Paarlberg, R.L., 2000, Genetically Modified Crops in Developing Countries: Promise or Peril?, Environment 42, 1, January/February 2000: 19-27.

- Paarlberg, R.L., 2001, The politics of Precaution: Genetically Modified Crops in Developing Countries, Baltimore and London, The Johns Hopkins University Press for IFPRI.
- Pardey, P.G., (ed.), 2001, The Future of Food Biotechnology Markets, and Policies in an International Setting, Washington, IFPRI.
- Per Pinstrup-Andersen, and Marc J. Cohen, 2002, Freedom to choose: perspectives on modern biotechnology and developing countries' food and agriculture, Eurochoices, Number 1, pp. 22-27.
- Pinstrup-Andersen, P., (ed.), 2001, Appropriate Technology for Sustainable Food Security, 2020 Vision Focus 7, Washington, IFPRI, accessible at http://www.ifpri.org.
- Pinstrup-Andersen, P., and Cohen, M.J., 2001, Modern Agricultural Biotechnology and Developing country Food Security, in Gerald C. Nelson, (ed.), Genetically Modified Organisms in Agriculture, London, Academic Press.
- Pinstrup-Andersen, P., and Schioler, E., 2001, Seeds of Contention: World Hunger and the Global Controversy Over GM Crops, Baltimore and London, The Johns Hopkins University Press.
- Pray, Carl E., Jikun, Huang, Rinfa, Hu and Scott Rozelle, Fall 2002, Five Years of Bt-cotton in China - The Benefits Continue, Plant Journal.
- Tollens, Eric, 1998, Food Security: Incidence and Causes of Food Insecurity among Vulnerable Groups and Coping Strategies, CTA Seminar on Food Insecurity in ACP Countries: Policy and Program Interventions Affecting Vulnerable Groups, Leuven, 26-30 October.

- Tollens, Eric, 28 October 1999, Livestock in Developing Countries: Socio-Economic Aspects, 7th annual meeting of the Flemish society of veterinary epidemiology & economics (VEE), Mercure Diamond Hotel, Antwerpen,.
- UNFPA, 2001, World Population Prospects: The 2000 Revision, New York, Vol. 1.

Appendix

Table 1: Global area of transgenic crops in 2000, by country (million hectares and %)

Country	2000	%
USA	30.3	68
Argentina	10.0	23
Canada	3.0	7
China	0.5	1
South Africa	0.2	<1
Australia	0.2	<1
Total	**44.2**	**100**

Source: Clive James, 2000

Table 2: Global area of transgenic crops in 2000, by crop (million hectares and %)

Crop	2000	%
Soybean	25.8	58
Maize	10.3	23
Cotton	5.3	12
Canola	2.8	7
Potato	<0.1	<1
Squash	<0.1	<1
Papaya	<0.1	<1
Total	**44.2**	**100**

Source: Clive James, 2000

Table 3: Global area of transgenic crops in 2000, by trait (million hectares)

Trait	2000	%
Herbicide tolerance	32.7	74
Insect resistance (Bt)	8.3	19
Bt/Herbicide tolerance	3.2	7
Virus resistance/Other	<0.1	<1
Global Totals	**44.2**	**100**

Source: Clive James, 2000

Table 4: Dominant transgenic crops, 2000

Crop	Million Hectares	% Transgenic
Herbicide tolerant soybean	25.8	59
Bt Maize	6.8	15
Herbicide tolerant canola	2.8	6
Herbicide tolerant maize	2.1	5
Herbicide tolerant cotton	2.1	5
Bt/Herbicide tolerant cotton	1.7	4
Bt cotton	1.5	3
Bt/Herbicide tolerant maize	1.4	3
Total	**44.2**	**100**

Source: Clive James, 2000

Table 5: Transgenic crop area as % of global area of principal crops, 2000 (million hectares)

Crop	Global area	Transgenic crop area	Transgenic area as % of global area
Soybean	72	25.8	36
Cotton	34	5.3	16
Canola	25	2.8	11
Maize	140	10.3	7
Total	**271**	**44.2**	**16**

source: Clive James, 2000

Table 6: Bt-cotton in China: yields, costs, and pesticide use by cotton varieties in the sampled households, 1999 (U.S. dollars are converted from yuan at 8.25 exchange rate and to ppp terms by multiplying by 4,2933)

			Pesticide use per hectare		
Variety of cotton	Yield (kg/ha)	Total production costs per kg cotton (US$/kg)	Number of applications	Quantity (kg)	Cost (US dollars)
With Bt	3371	1.61	6.6	11.8	136
Without Bt	3186	2.23	19.8	60.7	762

Source: Jikun Huang, Scott Rozelle, Carl Pray, Qinfang Wang, Plant Biotechnology in China, Science, Vol. 295, 25 january 2002, p. 676

List of Available Working Papers

nr. 1 BEERLANDT, H. en L. DRIESEN, *Criteria ter evaluatie van 'duurzame landbouw'*, Afdeling Landbouweconomie, K.U.Leuven, januari 1994, 35 p.

nr. 2 BEERLANDT, H. en L. DRIESEN, *Evaluatie van herbicide-resistente planten aan criteria voor duurzame landbouw,* Afdeling Landbouweconomie, K.U.Leuven, januari 1994, 39 p.

nr. 3 BEERLANDT, H. en L. DRIESEN, *Evaluatie van bovine somatotropine aan criteria voor duurzame landbouw*, Afdeling Landbouweconomie, K.U.Leuven, januari 1994, 63 p.

nr. 4 BEERLANDT, H. en L. DRIESEN, *Evaluatie van gemanipuleerde planten met biopesticide eigenschappen afkomstig van Bacillus thuringiensis aan criteria voor duurzame landbouw,* Afdeling Landbouweconomie, K.U.Leuven, januari 1994, 32 p.

nr. 5 BEERLANDT, H. en L. DRIESEN, *Evaluatie van haploide planten aan criteria voor duurzame landbouw,* Afdeling Landbouweconomie, K.U.Leuven, januari 1994, 17 p.

nr. 6 BEERLANDT, H. en L. DRIESEN, *Evaluatie van genetische technieken voor diagnosebepaling, immunologische technieken ter verbetering van de landbouwproduktie en transgene dieren en planten als bioreactor aan criteria voor duurzame landbouw,* Afdeling Landbouweconomie, K.U.Leuven, januari 1994, 28 p.

nr. 7 BEERLANDT, H. en L. DRIESEN, *Evaluatie van verbetering van de stikstoffixatie bij planten aan criteria voor duurzame landbouw,* Afdeling Landbouweconomie, K.U.Leuven, januari 1994, 17 p.

nr. 8 BEERLANDT, H. en L. DRIESEN, *Evaluatie van porcine somatotropine aan criteria voor duurzamelandbouw,* Afdeling Landbouweconomie, K.U.Leuven, januari 1994, 29 p.

nr. 9 BEERLANDT, H. en L. DRIESEN, *Evaluatie van tomaten met een langere houdbaarheid aan criteria voor duurzame landbouw,* Afdeling Landbouweconomie, K.U.Leuven, februari 1994, 30 p.

nr. 10 CHRISTIAENSEN, L., *Voedselzekerheid: van concept tot actie: een status questionis,* Afdeling Landbouweconomie, K.U.Leuven, april 1994, 106 p.

nr. 11 CHRISTIAENSEN, L. and J. SWINNEN, *Economic, Institutional and Political Determinants of Agricultural Production Structures in Western Europe,* Afdeling Landbouweconomie, K.U.Leuven, May 1994, 40 p.

nr. 12 GOOSSENS, F., *Efficiency and Performance of an Informal Food Marketing System, The case of Kinshasa, Zaire,* Afdeling Landbouweconomie, K.U.Leuven, July 1995, 41 p.

nr. 13 GOOSSENS, F., *Failing Innovation in the Zairian Cassava Production System, A comparative historical analysis,* Afdeling Landbouweconomie, K.U.Leuven, July 1995, 18 p.

nr. 14 TOLLENS, E., *Cadre conceptuel concernant l'analyse de la performance économique des marchés,* Projet-FAO "Approvisionnement et Distribution Alimentaires des Villes de l'Afrique Francophone", Afdeling Landbouweconomie, K.U.Leuven, août 1995, 35 p.
(Deuxieme version, avril 1996)

nr. 15 TOLLENS, E., *Les marchés de gros dans les grandes villes Africaines, diagnostic, avantages et éléments d'étude et de développement,* Projet-FAO "ApprovisioMement et Distribution Alimentaires des Villes de l'Afrique Francophone", Afdeling Landbouweconomie, K.U.Leuven, août 1995, 23 p.
(Deuxieme version, septembre 1996, 32 p.)

nr. 16 ENGELEN, G., *Inleiding tot de landbouwvoorlichting* (heruitgave), Afdeling Landbouweconomie, K.U.Leuven, augustus 1995, 17 p.

nr. 17 TOLLENS, E., *Agricultural Research and Development towards Sustainable Production Systems: I. Information Sources, Surveys; II. Conceptualisation of the Change Process,* NATURA-NECTAR course: "Agricultural Economics and Rural Development", module 1, Afdeling Landbouweconomie, K.U.Leuven, August 1995

nr. 18 TOLLENS, E., *Planning and Appraising Agricultural Development programmes and Projects: I. Farm Planning; II. Aggregation, Sensitivity Analyses and Farm Investment Analysis; III. Guidelines on Informal Surveys and Data Collection,* NATURA-NECTAR course: "Agricultural Economics and Rural Development", module 2, Afdeling Landbouweconomie, K.U.Leuven, September 1995

nr. 19 TOLLENS, E., *Structural Adjustment and Agricultural Policies: I. Market Theory: the State and the Private Sector; II. Output Markets and Marketing Institutions; III. Input Markets; IV. Case Study: Cameroon,* NATURA-NECTAR course: "Agricultural Economics and Policy Reforms", module 1, Afdeling Landbouweconomie, K.U.Leuven, September 1995

nr. 20 TOLLENS, E., *Theory and Macro-Economic Measures of Structural Adjustment – Methods of Evaluation and Linkages to the Agricultural Sector: I. Development Models and the Role of Agriculture,* NATURA-NECTAR course: "Agricultural Economics and Policy Reforms", module 2, Afdeling Landbouweconomie, K.U.Leuven, September 1995 nr. 21 TOLLENS, E., *Theory and Macro-Economic Measures of Structural Adjustment – Methods of Evaluation and Linkages to the Agricultural Sector: II. Implementation of Policy Reforms: Case Study of Market Liberalisation in Cameroon for Cocoa and Coffee,* NATURA-NECTAR course: "Agricultural Economics and Policy Reforms", module 2, Afdeling Landbouweconomie, K.U.Leuven, September 1995

nr. 22 TOLLENS, E., *Supply Response within the Farming Systems Context: I. Input Supply and Product Markets; II. Agricultural Supply Response Assessment,* NATURA-NECTAR course: "Agricultural Economics and Policy Reforms", module 3, Afdeling Landbouweconomie, K.U.Leuven, September 1995

nr. 23 GOOSSENS, F., *Agricultural Marketing and Marketing Analysis: I. Agricultural Marketing Research Frameworks. II. Agricultural Market Performance Criteria and The Role of Government Intervention,* NATURA-NECTAR course: "Agricultural Economics and Rural Development", module 3, Afdeling Landbouweconomie, K.U.Leuven, September 1995

nr. 24 GOOSSENS, F., *Agricultural Marketing and Marketing Analysis: Demand Analysis,* NATURA-NECTAR course: "Agricultural Economics and Rural Development", module 3, Afdeling Landbouweconomie, K.U.Leuven, September 1995

nr. 25 CHRISTIAENSEN, L. en H. BEERLANDT, *Belgische voedselhulp geanalyseerd met betrekking tot voedselzekerheid,* Afdeling Landbouweconomie, K.U.Leuven, november 1994, 15 p.

nr. 26 CHRISTIAENSEN, L. en H. BEERLANDT, *De Belgische ontwikkelingssamenwerking met Rwanda geanalyseerd met betrekking tot voedselzekerheid,* Afdeling Landbouweconomie, KU.Leuven, november 1995, 36 p.

nr. 27 BEERLANDT, H., *Identificatie van de meest kwetsbaren in Monduli distrikt, Arusha regio, Tanzania,* A.C.T.- Afdeling Landbouweconomie, K.U.Leuven, april 1995, 40 p.

nr. 28 BEERLANDT, H., TOLLENS, E. and DERCON, S., *Methodology for Addressing Food Security in Development Projects, Identification of the Food Insecure and the Causes of Food Insecurity based on Experiences from the Region of Kigoma, Tanzania,* Department of Agncultural Economics and Centre for Economic Research, K.U.Leuven, Leuven, December 1995, 19 p.

nr. 29 BEERLANDT, H., *Koppelen van noodhulp en strukturele ontwikkelingssamenwerking: opties voor een Belgisch beleid,* Afdeling Landbouweconomie, K.U.Leuven, december 1995, 23 p.

nr.30 TOLLENS, E., *La crise agraire au Zaïre: pour quelle politique de développement dans la phase de transition?,* Une contribution au colloque “Le Zaïre en Chantier: Quels Projets de Societé”, Anvers, 18 février 1993, December 1995, 14 p.

nr.31 GOOSSENS, F., *Rôle des systemes d'alimentation dans la securité alimentaire de Kinshasa,* Une contribution au projet GCP/RAF/309, AGSM, FA0, mai 1996, 78 p.

nr.32 BEERLANDT, H., DERCON, S., and SERNEELS, I., (Project co-ordinator: E. TOLLENS), *Tanzania, a Food Insecure Country?,* Department of Agricultural Economics, Center for Economic Research, K.U.Leuven, September 1996, 68 p.

nr. 33 TOLLENS, E., *Food security and nutrition 2. Case study from Tanzania,* Nectar Programme, Agricultural Economics and Policy Reforms, module 4, Afdeling Landbouweconomie, K.U.Leuven, Septembre 1996, 47 p.

nr. 34 BEERLANDT, H., en SERNEELS, J., *Voedselzekerheid in de regio Kigoma, Tanzania,* Afdeling Landbouweconomie en Centrum voor Economische Studiën, K.U.Leuven, september 1996, 45 p.

nr. 35 BEERLANDT, H., *Identificatie van verifieerbare indicatoren ter toetsing van de voedselzekerheidssituatie in de regio Arusha, Tanzania,* Afdeling Landbouweconomie, K.U.Leuven, november 1996, 60 p.

nr. 36 GOOSSENS, F., *Commercialisation des vivres locaux en Afrique Subsaharienne, le secteur informel dans un perspectif dynamique,* Une contribution au projet GCP/RAF/309, AGSM, FAO, novembre 1996, 58 p.

nr. 37 GOOSSENS, F., *The Economics of Livestock Systems: I. Marketing Problems and Channels of Livestock in Subsahara Africa,* NATURA-NECTAR course: "Agricultural Economics and Rural Development", module 4, Afdeling Landbouweconomie, K.U.Leuven, November 1996.

nr. 38 GOOSSENS, F., *The Economics of Livestock Systems: II. Price Stabilization in the Livestock Sector,* NATURA-NECTAR course: "Agricultural Economics and Rural Development", module 4, Afdeling Landbouweconomie, K.U.Leuven, November 1996.

nr.39 GOOSSENS, F., *The Economics of Livestock Systems: III. Consumer Demand for Livestock Products,* NATURA-NECTAR course: "Agricultural Economics and Rural Development, module 4, Afdeling Landbouweconomie, K.U.Leuven, November 1996.

nr. 40 JASPERS, N., *I. La Seguridad Alimenticia en el departamento de Quiché: Identificación e Impacto del Programa de Créditos, II. Informe Sobre Estudio Seguridad Alimenticia,* ACT - Afdeling LandbwAuweconomie, K.U.Leuven, November 1996, 39 p.

nr. 41 TOLLENS, E., *Social indicators with an illustration from Thailand,* NATURA-NECTAR course: "Agricultural Economics and Policy Reforms", module 4, Afdeling Landbouweconomie, K.U.Leuven, January 1997, 38 p.

nr. 42 BEERLANDT, H., en SERNEELS, J., *Handleiding voor een voedselzekerheidsdiagnose,* Afdeling Landbouweconomie en Centrum voor Economische Studiën, K.U.Leuven, februari 1997, 131 p.

nr. 43 BEERLANDT, H., and SERNEELS, J., *Manual for a Food Security Diagnosis,* Department of Agricultural Economics and Center for Economic Research, K.U.Leuven, March 1997, 125 p.

nr. 44 GOOSSENS, F., *Aangepaste vormen van samenwerking als hefboom voor de sociaal-economische promotie van boeren in het zuiden - algemene conclusies,* Seminarie georganizeerd door Ieder Voor Allen, Brussel, 17-18 maart 1997, 8 p.

nr. 45 GOOSSENS, F., *Commercialisation des vivres locaux en Afrique Subsaharienne - neuf études de cas,* Afdeling Landbouweconomie, K.U.Leuven, Mai 1997, 50 p.

nr. 46 BEERLANDT, H., en SERNEELS, J., *Food Security in the Kigoma Region of Tanzania,* Department of Agricultural Economics and Center for Economic Research, K.U.Leuven, May 1997, 42 p.

nr. 47 BEERLANDT, H., and SERNEELS, J., *Manuel Pour un Diagnostic de Securité Alimentaire,* Département d'Economie Agricole et le Centre d'Etudes Economiques, K.U.Leuven, Juillet 1997, 134 p.

nr. 48 GOOSSENS, F., *Rural Services and Infrastructure - Marketing Institutions,* NATURA-NECTAR course: "Agricultural Economics and Policy Reforms", module 4, Afdeling Landbouweconomie, K.U.Leuven, June 1997, 20 p.

nr. 49 TOLLENS, E., *International Trade and Trade Policy in Livestock and Livestock Products,* NATURA-NECTAR COURSE: "Agricultural Economics and Rural Development", module 4, Afdeling Landbouweconomie, K.U.Leuven, October 1997,43 p.

nr. 50 DESMET, A., *Working towards autonomous development of local farmer organisations: which role for development agencies?,* Department of Agricultural Economics and Center for Economic Research, March 1998, 49 p.

nr. 51 TOLLENS, E., *Catalogue de titres dans la bibliotheque ALEO sur le Zaïre - Congo,* Département d'Economie Agricole, Mars 1998, 96 p.

nr. 52 DEMONT, M., JOUVE, P., STESSENS, J., et TOLLENS, E., *Evolution des systèmes agraires dans le Nord de la Côte d'Ivoire: les débats « Boserup versus Malthus » et « compétition versus complémentarité » révisités*, Département d'Economie Agricole et de l'Environnement, K.U.Leuven, Avril 1999, 43 p.

nr. 53 DEMONT, M., and TOLLENS, E., *The Economics of Agricultural Biotechnology: Historical and Analytical Framework*, Department of Agricultural and Environmental Economics, K.U.Leuven, October 1999, 47 p.

nr. 54 DEMONT, M., en TOLLENS, E., *Biologische, biotechnologische en gangbare landbouw : een vergelijkende economische studie*, Afdeling Landbouw- en Milieueconomie, K.U.Leuven, Maart 2000, 53 p.

nr. 55 DEMONT, M., JOUVE, P., STESSENS, J., and TOLLENS, E., *The Evolution of Farming Systems in Northern Côte d'Ivoire: Boserup versus Malthus and Competition versus Complementarity*, Department of Agricultural and Environmental Economics, K.U.Leuven, August 2000, 25 p.

nr. 56 DEMONT, M., and TOLLENS, E., *Economic Impact of Agricultural Biotechnology in the EU: The EUWAB-project*, Department of Agricultural and Environmental Economics, K.U.Leuven, January 2001, 16 p.

nr. 57 DEMONT, M., and TOLLENS, E., *Reshaping the Conventional Welfare Economics Framework for Estimating the Economic Impact of Agricultural Biotechnology in the European Union*, Department of Agricultural and Environmental Economics, K.U.Leuven, March 2001, 32 p.

nr. 58 DEMONT, M., and TOLLENS, E., *Uncertainties of Estimating the Welfare Effects of Agricultural Biotechnology in the European Union*, Department of Agricultural and Environmental Economics, K.U.Leuven, April 2001, 81 p.

nr. 59 DEMONT, M., and TOLLENS, E., *Welfare Effects of Transgenic Sugarbeets in the European Union: A Theoretical Ex-Ante Framework*, Department of Agricultural and Environmental Economics, K.U.Leuven, May 2001, 39 p.

nr. 60 DE VENTER, K., DEMONT, M., and TOLLENS, E., *Bedrijfseconomische impact van biotechnologie in de Belgische suikerbietenteelt*, Afdeling Landbouw- en Milieueconomie, K.U.Leuven, Juni 2002, 66 p.

nr. 61 DEMONT, M., and TOLLENS, E., *Impact of Agricultural Biotechnology in the European Union's Sugar Industry*, Department of Agricultural and Environmental Economics, K.U.Leuven, June 2002, 55 p.

nr. 62 DEMONT, M., and TOLLENS, E., *The EUWAB-Project: Discussion*, Department of Agricultural and Environmental Economics, K.U.Leuven, August 2002, 20 p.

nr. 63 DEMONT, M., DELOOF, F. en TOLLENS, E., *Impact van biotechnologie in Europa: de eerste vier jaar Bt maïs adoptie in Spanje*, Afdeling Landbouw- en Milieueconomie, K.U.Leuven, Augustus 2002, 41 p.

nr. 64 TOLLENS, E., *Food Security: Incidence and Causes of Food Insecurity among Vulnerable Groups and Coping Strategies*, Department of Agricultural and Environmental Economics, K.U.Leuven, September 2002, 30 p.

nr. 65 TOLLENS, E., *La sécurité alimentaire: Incidence et causes de l'insécurité alimentaire parmi les groupes vulnérables et les strategies de lutte*, Département d'Economie Agricole et de l'Environnement, K.U.Leuven, Septembre 2002, 33 p.

nr. 66 TOLLENS, E., *Food Security in Kinshasa, Coping with Adversity*, Department of Agricultural and Environmental Economics, K.U.Leuven, September 2002, 35 p.

nr. 67 TOLLENS, E., *The Challenges of Poverty Reduction with Particular Reference to Rural Poverty and Agriculture in sub-Saharan Africa*, Department of Agricultural and Environmental Economics, K.U.Leuven, September 2002, 31 p.

nr. 68 TOLLENS, E., *Het voedselvraagstuk*, Afdeling Landbouw- en Milieueconomie, K.U.Leuven, September 2002, 71 p.

nr. 69 DEMONT, M., WESSELER, J., and TOLLENS, E., *Biodiversity versus Transgenic Sugar Beet: The One Euro Question*, Department of Agricultural and Environmental Economics, K.U.Leuven, November 2002, 33 p.

nr. 70 TOLLENS, E., and DEMONT, M., *Biotech in Developing Countries: From a Gene Revolution to a Doubly Green Revolution?*, Department of Agricultural and Environmental Economics, K.U.Leuven, November 2002, 8 p.

nr. 71 TOLLENS, E., *Market Information Systems in Liberalized African Export Markets: The Case of Cocoa in Côte d'Ivoire, Nigeria and Cameroon*, Department of Agricultural and Environmental Economics, K.U.Leuven, November 2002, 19 p.

nr. 72 TOLLENS, E., *Estimation of Production of Cassava in Bandundu (1987-1988) and Bas Congo (1988-1989) Regions, as Compared to Official R.D. Congo statistics*, Department of Agricultural and Environmental Economics, K.U.Leuven, December 2002, 29 p.

nr. 73 TOLLENS, E., *Biotechnology in the South: Absolute Necessity or Illusion?*, Department of Agricultural and Environmental Economics, K.U.Leuven, December 2002, 29 p.

nr. 74 DEMONT, M., BONNY, S., and TOLLENS, E., *Prospects for GMO's in Europe*, Department of Agricultural and Environmental Economics, K.U.Leuven, January 2003.