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Transgenic seeds in developing countries – experience, challenges, perspectives

Summary

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SUMMARY

In the course of the intensive debate on sustainable production of food and fodder, bioenergy and renewable raw materials, the discussion of using genetic engineering in plant breeding and the application of the transgenic seeds resulting from this in Europe and worldwide has undergone a shift in focus – the potentials and the contributions made so far as well as possible future ones to the solution of specific problems are now in greater demand. The current report also emphasises this particularly, without ignoring the risk issues. In this regard, the central results of the TAB project can be summarized as follows:

> The benefit of using transgenic seeds in developing and emerging countries so far seems limited with regard to the range of plant varieties, types and features.
> The data on the socio-economic effects continue to be weak and do not even allow a final evaluation of the business and economic effects so far (yields, profits, and profit distribution, sector income).
> To evaluate transgenic types, one should consider alternative knowledge-based options, e.g., of integrated plant protection, and not the status quo in agricultural practice which is often ecologically and socio-economically deficient.
> The commercially available transgenic plant varieties and at least also those that are developed to an advanced stage only represent a small selection of the potential genetically engineered breeding approaches imaginable in principle. The reasons for this can be found in the lack of scientific and economic capacities in most developing countries, in controlling procedures and products by the patent owners and in frequently insufficient risk regulation.
> The question of whether genetically modified plants can offer sustainable, regionally adapted options for differently developed agrarian economies in the medium and long-term future cannot currently be answered in a substantiated way.
> The potential of genetically engineered breeding approaches should be tested in the framework of a differentiated, problem-oriented approach in the search for sustainable agrarian technologies and cultivation methods without a predetermined outcome.

STARTING POINT AND ISSUE

Effects of using transgenic seeds on the economic, social and political structures in developing countries – is this topic relevant at all? Three reasons in particular indicate that it is:

> Since the conference in Rio in 1992, the industrial nations have committed themselves to supporting developing countries in the sustainable, fairly advantaged, and secure use of biological diversity, also with methods from genetic engineering. A particular focus here is on the creation and further development of suitable framework conditions.
> In the past few years, there has been a strong increase in the distribution of genetically modified varieties particularly in emerging countries. There is now extensive commercial cultivation of transgenic cotton by small-scale farmers in China and India.
> The search for the best possible agrarian technologies has been given an enormous push forward in recent times by the renaissance of the significance of agriculture or the global production of renewable raw materials and their use. Since the transgenic plants available to date offer a rather narrow spectrum of options, the question arises as to the future potentials of genetically engineered breeding approaches, including those which have so far been overlooked.

Background, target, and procedure

Both proponents and opponents of the use of transgenic seeds in developing countries assume that genetic engineering is capable of far-reaching effects under the ecological, economic, social and institutional conditions of less developed and emerging countries. On the one hand, great expectations are placed on the contribution genetic engineering can make to food security and economic alignment with industrial countries, on the other hand there are great fears regarding disadvantageous effects on the economic methods of small-scale farmers and the traditional handling of seeds. The »mega-topic« of bioenergy which has generally intensified and sharpened the global debate on targets, pathways and priorities of future use of natural resources in the few years has also prompted the question of the potentials of agricultural biotechnology with a new dynamism. From the perspective of the proponents, genetic engineering is both an indispensable means of increasing acreage yields in arable farming overall and also for the specific optimisation of »energy plants«. Critics of agricultural biotechnology, by contrast, doubt these assessments and fear a potentisation of the negative consequences they assume regarding ecology, health and especially socio-economics.

The aim of the TAB project »Effects of Using Transgenic Seeds on the Economic, Social and Political Structures in Developing Countries«, proposed by the Committee for Economic Cooperation and Development and decided by the Committee for Education, Research and Technology Assessment, was to review the general status of information and debate (Chap. 2) and to record as concretely as possible how the use of transgenic seeds has actually developed in the past 12 years, which consequences can be identified, and what can be inferred from this for the future design of German (and also European) development policy (Chap. 5).

The focus of the report in terms of content are four case studies (Chap. 3) on countries with extensive use of genetically modified plants (Brazil, China) and those with only limited use of them (Chile, Costa Rica). In addition to these four countries, a number of others would be potential candidates (e.g. Argentina, India, Mexico, Paraguay, the Philippines, South Africa or Uruguay). However, no surveys could be commissioned here due to poor data, restricted project funding, or a lack of offers. The results of these country studies are discussed comparatively with a view to the central questions or objectives (Chap. 4): in the field of research and development, on the question of the economic results to date of cultivating transgenic plants, on other socio-economic effects and questions of participation and for recording, assessing and regulation risks.

TRANSGENIC PLANTS IN A GLOBAL PERSPECTIVE: ACTIVITIES AND DISCOURSES

Worldwide cultivation

In 2007, transgenic plants were cultivated in a total of 23 countries on around 114 million hectares, representing about 5% of arable land worldwide. These areas are concentrated very strongly on five countries in North and South America in which alone 88% of the acreage is located (USA: 57.7 million hectares; Argentina: 19.1 million hectares; Brazil 15.0 million hectares; Canada: 7.0 million hectares; Paraguay: 2.6 million hectares), on India (6.2 million hectares), China (3.8 million hectares) and South Africa (1.5 million hectares. Even after 12 years of cultivation, only two genetic traits, i.e. herbicide tolerance (HR) and insect resistance to *Bacillus thuringiensis* (Bt), either alone or in combination, account for 99.9% of cultivated genetically modified plants, in only four crop varieties (51.3% soybean, 30.8% maize, 13.1% cotton, and 4.8% rapeseed/canola).

Commercial cultivation has taken place up to now almost exclusively in the so-called emerging countries and is quite predominantly restricted to two cash crops: HR soybean in South America (Argentina, Brazil, Paraguay, and Uruguay) and Bt cotton in India and China. In addition there are HR and/or Bt corn acreages, above all in South Africa, Argentina and in the Philippines. Taken as a whole, the role of this cultivation is hardly ever for the purpose of ensuring food security or for local markets.

In some cases, these plant products which are processed and exported for fodder and textile manufacture are of great economic significance. Cotton, for instance, is China's most important agricultural product overall in terms of value, and about 70% of it is obtained from transgenic varieties/breeds. In Brazil, soybean is the central agricultural product, with about a 10% share of the entire export of the country, and in 2007 about two-thirds of it was produced with the aid of transgenic varieties.

Benefit questions: suitability, effect levels and results

The concept of benefit is just as multilayered as that of risk. In the report, three levels of significance are distinguished:

> The contribution played by transgenic seeds to achieving *superordinated legally protected goods and objectives* (e.g. food security and sovereignty, economic development, environmental protection and natural conservancy);
> The benefit related to the business and economic *size and distribution of profits* (among seed developers, suppliers and users);
> The suitability of genetic engineering in *plant breeding* to meet traditional or entirely new breeding goals.

The first level – effects on legally protected goods and development aims – is the highest level of aggregation in an overall evaluation of the use of transgenic seeds and is dependent to a high degree on value or position. The crucial elements are the underlying development model, suppositions and explanations of the cause of poverty and hunger, ecological concepts and objectives and the selection of impact sizes considered. For this reason, the stakeholders involved all come to completely different results.

To put it simply, there are two opposing perspectives: one on the (global) market economy level, one regional-ecological. The former regards genetically modified plants as an innovative production resource which should indeed aid even small-scale farmers in developing and emerging countries to produce more efficiently, i.e., with savings in costs and work, as well as with a secure yield; the latter sees genetic engineering or genetically modified plants as a basically unadapted technology which destroys the traditional local methods of cultivation, some of which have been handed down by the indigenous population. Between these two poles, there are more open, »searching« attitudes and methods of approach.

These aim to investigate the potentials of genetic engineering approaches in meeting plant-breeding objectives and to compare the performance of transgenic varieties with that of conventional varieties and, where appropriate, with alternative cultivation techniques, without having preconceived ideas about the outcome.

The second level of consideration or question – regarding the business and economic size and distribution of profits from development and cultivation – is ostensibly the most concrete level and should in fact be amenable to empirical recording and a quantitative analysis, at least after more than 10 years of commercial cultivation. A more extensive discussion of the (surprisingly limited) state of knowledge here is provided in the context of evaluating the case studies.

The third level – the assessment of the suitability and use of genetic engineering in plant breeding – also ostensibly appears to be an internal scientific question that can in principle be investigated by sober scientific analysis. However, because the issue here is a prognosis for possible future successes, a broad field is opened up here for speculation that follows specific interests and arguments among experts from different fields (molecular biology, plant breeding, agricultural economy) and social actors (publicly financed plant or breeding research, »classical« plant breeding, or even biotechnology companies, nature conservancy and environmental protection agencies, development organisations).

Breeding aims and genetic engineering approaches

A comprehensive *analysis of the potential of using genetic engineering for breeding aims specific to developing countries* could not be conducted within the limits of the projects. For this it would be necessary to compare the challenges and aims of plant breeding countrywise or at least for the larger regions in a differentiated and detailed way using both approaches with and without genetic engineering implemented to date and in the foreseeable future. What is provided is a brief overview of breeding aims and genetic engineering approaches.

The *crop yield*, both of individual parts and of the plant as a whole, is determined multifactorially as a complex feature and up to now genetic engineering has only been able to exert a minor influence on it. Improving the plants' resistance to influences that *reduce* the crop yield or quality such as diseases and pests or lack of nutrients and water, i.e., the creation of resistance or tolerance in order to *secure crop yield* can be partly procured through individual features or just a few characteristics and is thus in principle more accessible to genetic engineering. In addition to the varieties grown up to now that are resistant to insects and herbicides, there has been intensive research for many years above all into variants that are resistant to viruses and fungi. Up to now, a number of virus-resistant varieties have been licensed and grown on limited acreages, including peppers and tomatoes in China, and pumpkin and papaya in the USA. Similarly, resistance or tolerance to cold, drought, or salinity that can be used by genetic engineering has also long been the subject of research, and in the current debate has moved more into the limelight. The first concrete example was reported in the autumn of 2008 by BASF and Monsanto, namely the advanced development of a drought-tolerant maize variety.

In the area of the *quality characteristics* of plants, genetically engineered modifications with the aim of obtaining new, industrially practicable substances such as »plant-made industrials« or »plant-made pharmaceuticals« is a central feature of many R&D projects, but so far any concrete use has been of little significance. In this regard, there are hardly any perceptible aspects specific to developing countries, with the exception of the biofortification approach, i.e., the (genetically engineered) enrichment of basic foodstuffs with vitamins or essential minerals. Relevant projects are being pursued for the target group of poor populations in Africa and Asia and have been promoted for some time on a larger scale by the Bill and Melinda Gates Foundation; the example of »Golden Rice« which has achieved particularly good progress is discussed in depth in the report.

Risks: dimensions and debates

In view of the size and diversity of the topic of risk, the report concentrates on a succinct overview of risk dimensions and debates and works out the questions which are or could be particularly relevant for developing countries. A distinction is made between health, ecological and socio-economic risks.

The crucial factor in deciding whether or which effects of using transgenic varieties should be regarded as risks or damage is the standard used for comparison. The latter is coloured by the status quo of agricultural practice and the relevant guiding principle used in agriculture. Differences can already be seen among the comparatively homogeneous EU countries, and these are even stronger in the face of the diverse nature of emerging and developing countries.

In considering which risk aspects, levels and chains of effect are particularly relevant for or indeed specific to developing and emerging countries, two dimensions can be distinguished: The type and size of the risks are marked strongly by the conditions of geography and natural space, their controllability by »development-related« and institutional parameters. With regard to the parameters of *geography and natural space*, questions regarding biological diversity come up more strongly in some developing and emerging countries than they do in European countries, for example, especially when they house so-called centres of biological diversity that are regarded as particularly important and worthy of protection or other regions that are the source of agricultural crop plants.

With regard to the *development-related* parameters, one important topic consists of questions pertaining to their regulation or establishment and realization; here it is virtually regarded as a consensus in the debate that in many or most developing and emerging countries there continues to be great deficiency in terms of institutions and capacities. On the part of the users, the effects of using high-performance transgenic seeds can be influenced particularly by the level of education and knowledge as well as by the amount of capital in the businesses. It is crucial for the possible effects on environment and health that Good Agricultural Practice is observed, e.g., in using pesticides. New varieties can also lead to changes in land usage over a wide area and thus have effects on the ecology. The dominant topic here in the risk debate on the implementation of transgenic varieties in developing and emerging countries are, however, the related socio-economic and to some extent also socio-cultural questions, e.g., with regard to the effects on traditional crop-growing methods and seed markets.

It is particularly difficult to systematise the socio-economics risks involved in the use of transgenic seeds because opinions differ very greatly regarding the effects which are to be attributed at all to the distribution and use of genetically modified plants and whether these should be regarded as risks or damage. While it is possible at least to a certain degree to prospectively deduce and investigate possible ecological and heath-related consequences from the new characteristics of transgenic varieties and their use in this connection, socio-economic consequences arise largely only in the situation of real commercialisation, cultivation, and use. The data on this, however, are surprisingly weak, even in industrial countries.

In the emerging and developing countries, the question of market power and market behaviour of the large »biotech« seed suppliers plays a great role. This is in part bound up with far-reaching fears regarding the destruction of traditional production methods in a multifunctional agriculture. Overall, the complex and heterogeneous socio-economic effects can be regarded as the actual centre of the risk debates in the emerging and developing countries, since they are often bound up with the question of basic development models, aims, and approaches.

Particular general framework in developing countries

Even after 20 years of research and 12 years of cultivation, there are as yet hardly any transgenic varieties in the real sense that are specific to developing countries. It is controversial whether the reasons for this lie primarily in the technology itself, in the interests of the technology owners, or was caused by (overly) strict licensing conditions. There are, however, adapted HR and Bt varieties, mainly as a result of hybridisation into regional varieties.

Although there were and still are a large number and variety of research and development projects overall on transgenic plants for the particular benefit of agriculture in developing countries – in the countries in question, in international agricultural research centres, and in some cases in cooperation with institutions in industrial countries –, these seem as ever to be mainly at early stages (and not readily amenable to assessment). It is widely assumed that worldwide up to now comparatively few resources have been used, from which it is inferred that the actual potential of transgenic plants has not yet been properly determined for developing countries. Proponents of a stronger use of genetically modified crops additionally emphasize that regulatory and administrative licensing and cultivation conditions in connection with continuingly inadequate capacities in science administration have prevented further successes in development. It is indisputable that, regardless of type and implementation, specific regulation of transgenic plants makes its research and development more expensive than that of non-transgenic, conventional plants or varieties.

With a view to the development and use of transgenic seeds in developing countries, questions of intellectual property and the establishment and implementation of patent and licensing claims play a central role. A model which has increasingly been seen in the past few years to overcome the problems of licensing are so-called public-private partnership projects. Here the technology owners make their patented genetic engineering applications or varieties available licence-free to publicly financed research institutions for specific purposes. A procedure of this kind is one important basis of the »Golden Rice« project. As an example of the specific use of plant biotech for a superordinated development goal (the reduction of malnutrition and the detriments to health ensuing from this), this seems indeed to have realistic chances of success if it is part of a comprehensive overall strategy. At the same time, it provides evidence of the enormous influence of the large, biotech-orientated seed and agricultural chemical companies, and it raises the question of whether this kind of cooperation is a forward-looking and practicable model – a question which is taken up again in the context of the synopsis and outlook on possible options for action.

International regulation

The most important global efforts and levels of regulation that are significant for the use of transgenic seeds in developing and emerging countries pertain to the handling of biological diversity and plant-genetic resources, world trade (including the enforcement of intellectual property rights) as approaches to standardising risk estimation and assessment.

With regard to the Biodiversity Convention, it should be noted that the processes suggested by the Rio conference in 1992 are extremely protracted. For instance, there is still no binding set of rules for balancing out advantages in the use of biological diversity, but only (according to a resolution from the most recent Conference of the Parties) the order to draw up a quorate text under German responsibility by the next Conference of the Parties in 2010. The clearly more advanced biosafety or Cartagena protocol came into force in 2003 and for the first time regulates bindingly in international law the cross-border transport, management and handling of genetically modified organisms. At present, 148 nations are contracting parties in the protocol. However, important countries which cultivated genetically modified plants such as Argentina, Canada and the USA have not so far joined the Cartagena protocol. So far, there is no final regulation on the labelling of agricultural products which *may* contain certain amounts of genetically modified organisms. At present, it is sufficient to provide a declaration that the product »may contain genetically modified organisms« if the potential genetically modified organism in question is licensed in the exporting country and has been judged to be safe. A central topic in the latest Conference of the Parties in May 2008 in Bonn was the question of liability and compensation for »damage to biodiversity« by genetically modified organisms. The result was not the possible rules themselves for this but the decision that this should be bindingly put in place.

In the spirit of the Rio conference, the industrial countries should support the developing countries in implementing the Biodiversity Convention and its resolutions. The German Ministry for Economic Cooperation and Development promotes the establishment of capacities for evaluating risks involved in genetic engineering in the framework of the German Biosafety Capacity Building initiative. For instance, by supporting the »African Model Law« on biosafety, which was developed by the African Union in 2001 as a framework of guidelines and starting point for national regulations by it member states.

Prior to the Rio conference, there were already efforts at international regulation of access to so-called plant genetic resources, which represent an important source for breeding in general and thus also for the development of genetically modified plants. At the 22nd FAO conference in 1983, the »International Undertaking on Plant Genetic Resources« was adopted. This stipulates that the plant genetic resources should be kept free from individual claims as a common heritage of mankind. After the Biodiversity Convention had, however, placed genetic resources generally under the sovereignty of national states, a protracted process to harmonise the »Undertaking« and the Convention had to be set in motion. In 2001, an international contract for plant genetic resources for nutrition and agriculture resulted from this. It determines access to plant breeding material for the 35 most important food crops and the most important 29 fodder crops. At the same time it regulates balancing advantages for the countries of origin along the lines of the Biodiversity Convention.

Aspects of trading with genetically modified organisms related to commercial law are regulated in the treaties of the World Trade Organisation (WTO). For the field of agricultural biotechnology, several WTO treaties are relevant, in particular the SPS (Agreement on the Application of Sanitary and Phytosanitary Measures) and TRIPS agreements (Agreement on Trade-Related Aspects of Intellectual Property Rights). The latter obliges member states of the WTO to establish legal systems for intellectual property rights, whereby a patent reinforcement is possible or designated for transgenic varieties, which was not the case for conventional varieties. The question of whether protective systems for intellectual property rights really promote innovation and increase prosperity in an economy overall can only be answered in depth for a particular country, differentiated according to the type of protective system and affected object of protection (technology, process, product).

Besides these global regulation efforts derived from superordinated political goals (maintaining biological diversity, food security, free world trade, protection of intellectual property rights), there are some approaches towards internationally aligning risk assessment and the evaluation of transgenic seeds or genetically modified plants. Since the Cartagena protocol provides no specifications for health risk assessment, this has become the task of a working group of the Codex Alimentarius Commission of the FAO and WHO, which is responsible for international aspects of food security. Here not only basic principles are formulated but also detailed guidelines worked out for the (health-related) safety assessment of transgenic foods. Since the mid-1990s, the OECD has also been working on questions of risk evaluation and regulation under the specific perspective of harmonisation to permit world trade.

These (and other) guides to conducting safety evaluations ultimately only provide a framework. For the results of risk assessment and evaluation themselves, the crucial factors are how the responsible institutions are anchored, orientated, and equipped with regard to their capacities and competences. A central issue here is the extent to which the procedures and standards of the industrial countries can, must, or may be transferred to the developing and emerging countries. This is so relevant because on the one hand the scientific, political and social capacities for evaluating biosafety are still regarded to be very deficient at least in most developing countries and because on the other hand the socio-economic issues play a greater role in many developing and emerging countries. For these reasons, they could or should be accorded a different priority in the framework of risk evaluation too.

In addition to the international regulations and activities, there are unilateral requirements which are significant for the use of transgenic plants in developing and emerging nations. The effects of EU genetic engineering regulation and the growing requirements of the globally active food industry with regard to quality standards and documented origin are regarded here as particularly important. For many (developing) countries, the question arises as to whether cultivation of transgenic varieties reduces or indeed destroys the options of exporting to Europe. Establishing efficient systems of origin and traceability (so-called identity preservation) for agricultural products is regarded as particularly elaborate and hardly possible for less developed countries.

THE CASE STUDIES

The four sample countries Brazil, Chile, China and Costa Rica are relatively highly developed countries. The focus on Latin America has its advantages in that this area has by far the largest areas with genetically modified plants after North America and for Brazil the largest growth worldwide in agricultural use at all is assumed. At the same time there is a strong (opposition) movement in civil society in the whole of Latin America, so that social debate on the cultivation of transgenic plants is also being intensively conducted. The example of China represents the emerging nation with the greatest economic significance worldwide which sets great store on developing its scientific capacities, including explicitly those of biotech and genetic engineering.

China

China, the country with the largest population and with an enormous economic and technological capacity, has for many years relied on the development and use of genetically modified plants. Cotton is China's most important cash crop, and the share of transgenic varieties that are resistant to insects is approximately 70%. In comparison, other types of transgenic plants play a very subordinate role. Although the Bt cotton varieties initially stemmed from Monsanto, cheaper Bt varieties developed by the Chinese Academy of Agricultural Sciences now dominate the market. As is typical of the structure of Chinese agriculture, small-scale farmers are the primary users of these varieties. Almost exclusively, they plant cotton in small fields of less than 1 hectare (which is the reason that it has not been felt to be necessary to explicitly prescribe the use of refuge areas to prevent the development of resistance in the cotton bollworm). In 1999–2001, according to spot checks in various provinces, the use of Bt varieties made it possible to significantly reduce the amount of insecticides used while simultaneously increasing the yield. As a result, the farms studied achieved significantly increased profits. In the following years, these effects were reduced due to a secondary pest problem, whose cause is a matter of controversy.

There is significant reluctance by the authorities to license transgenic food plants. Tomatoes, peppers, and chilli – for which there are licensed varieties that delay maturation or produce resistance to viruses – are hardly being planted. The largest use is apparently made of virus-resistant papaya. In the case of rice, the central food plant of Asia, the Chinese licensing authorities have rejected the commercialisation of transgenic varieties, explicitly referring to the precautionary principle. The case study makes it clear that the Chinese government has implemented comprehensive regulation of genetic engineering that since 2002, for example, foresees a process-based labelling requirement for food that contains ingredients from transgenic plants that is similar to the EU regulations. Despite the restrictive licensing for planting, there is a food sector in which transgenic products play a large role, namely the soybean market. Although the northeast of the country continues to be a region with a tradition of growing soybeans, China is by far the world's largest importer of soybean. While the imported soybean is primarily used for the production of soybean oil, it has still led to a massive fall in prices for Chinese soybean, which is primarily used for the production of tofu.

This case study cannot, however, provide a detailed image of the debates within China. That would be an unrealistic expectation considering the size of the country and the constraints on freedom of information that still exist. The study, however, does make it possible for us to recognise the facets of a truly heterogeneous situation. Although the details of the licensing situation of genetically modified plants may well be relatively obscure to the normal population, specific questions are increasingly becoming the object of public discussion in the media, such as the consequences of importing soybeans and the illicit planting of transgenic rice. The population overall seems to be (very) open to technology, but with a low level of knowledge as to the actual diffusion of transgenic food. Furthermore, a more sceptical group of consumers is developing among the urban, more affluent part of the population. It is among this group that NGOs critical of genetic engineering are beginning to exert some influence.

In the future, we can expect increased licensing of genetically modified plants, especially of domestically developed varieties. This will be oriented towards the requirements of the small-scale farms characteristic of Chinese agriculture. Factors that appear to be part of the Chinese leadership's thoughts on economic strategy include explicitly taking into consideration domestic public opinion, the scepticism toward genetic engineering in export markets (not only in European countries, but also in Japan, South Korea, and Hong Kong), and biosafety regulations that are oriented on the precautionary principle.

With a view to the high-level debates about genetically modified plants and developing countries, the following items thus determine the situation in China:

> The country has its own comprehensive scientific capacity, which made it possible for it to develop its own transgenic Bt varieties of cotton at an early point in time. This resulted in less dependence on transnational corporations, without completely expelling them from the market.
> Its agriculture is characterised by a largely homogeneous, small-scale organisation of farming. This makes it possible, for example, to avoid the possible ecological and also socio-economic consequences of large-scale monocultures.
> For a long time there has been elaborate biosafety legislation that strongly emphasises the precautionary principle. This includes regulations for a process-based labelling of transgenic food.
> Until now there has been a significant reluctance for the authorities to license the planting of transgenic food plants (e.g. rice). This can be explained by consideration of the export markets and presumably by their limited acceptance despite a tendency in the population to accept technology.

Brazil

Although Brazil has a much lower population than China, the area of the country is comparably large and the agricultural capacity is regarded as the largest by far worldwide and is far from exhausted. In the use of transgenic seeds, an entirely different situation is seen from that in China. The most important results are as follows:

> The country also has its own comprehensive scientific capacities, but so far has not been successful in developing its own transgenic varieties. Although there are some research activities taking place also on locally significant plant species (sugar cane, beans, potatoes, papaya), the release proposals are dominated clearly by multinational companies which concentrate on the cash crops of maize, cotton and soybean.
> Cultivation is restricted mainly to HR soybean, and since 2007 Bt cotton has been added to this. Bt and HR maize varieties are licensed in principle and their cultivation is expected in the 2008/2009 season.
> The history of diffusion of HR soybean (and similarly of Bt cotton) displays a specific idiosyncrasy: for years, transgenic soybean seeds from Monsanto, which came from Argentina, were illegally cultivated on a larger scale. This cultivation was legalised in a highly controversial court case which lasted for years, whereby the Brazilian government gave up the country's status as a major non-genetic engineering producer (especially for soybean for the European market). However, there continues to be a regional differentiation in the use of HR soybean with a focus in the southern state of Rio Grande do Sul.
> Among the users, most are larger businesses but medium-sized and small-scale farmers also cultivate HR soybean, particularly as members of cooperatives which often provide the seeds centrally.
> There is an intensively conducted social controversy on the ecological and economic consequences of using transgenic seeds with a strong anti-genetic engineering movement on the one hand and a strong biotech lobby on the other.

On the socio-economic effects there are so far practically no hard numbers. HR plants can without question reduce the operating costs for weed control, but the size of these effects and of a possible profit increase depends on the type of business, seed prices, and the price development of the product, e.g. soybean. Concentrating too strongly on a cash crop that is temporarily particularly lucrative makes small businesses in particular very prone to disruption (in principle, of course, regardless of the type of seed) from a reduction in demand. Viewed economically, it is relevant to ask whether Brazil wants to produce and export soybean and maize on a larger scale which is certified free of genetic engineering within the framework of a double strategy for a longer time.

The biosafety legislation of the country seems to be comprehensive but its application (e.g., labelling regulations) are judged controversially or to some extent strongly criticised. It was and is characteristic of the development of this regulation that the cultivation and import of genetically modified organisms were legalised stepwise by presidial decrees and subsequent parliamentary endorsements.

In the future, it is expected that the number of transgenic varieties and the size of the production areas will clearly increase. Particularly the soybean acreages are to be enormously extended once again, for biodiesel fuel production for instance. In the course of extending sugar cane cultivation (as a bioenergy supplier) too, transgenic varieties will probably be used as soon as they are available and licensed. Many think that the conventional production sector will long term become a niche or special market.

Concerns are being expressed on many sides with regard to the monopoly position of the international biotechnology companies, and there are doubts that some agricultural sectors, particularly ecological farming, may suffer disadvantages if there are no regulatory stipulations which guarantee true coexistence.

Costa Rica

As a Central American country which is small not only in comparison to Brazil and China and which is characterised by relatively comprehensive democratic development and social stability by Latin American standards, Costa Rica is subject to quite different conditions for the implementation of transgenic seeds and their effects. The following appear to be particularly striking here:

> There is no cultivation for *use* in the country itself, but exclusively for *producing seeds* for the world markets. This occurred particularly when transgenic varieties of soybean, maize and cotton were introduced onto the market and to some extent also in the preceding test phases.
> This meant that although seed propagation was carried out mostly on relatively small areas, it was at least at times very significant, particularly for US American seed companies.
> This test and propagation cultivation was carried out for many years de facto secretly without the public being actively informed and without the relevant releases being competently and thoroughly tested and monitored. Now that

awareness of the problems is greater, a specific biosafety legislation is currently in the parliamentary process.
> In the past few years, in the context of a vigorous social debate on further market liberalisation and opening in the country, an increasingly critical civil social involvement has developed on the question of cultivating genetically modified plants.

This special constellation makes Costa Rica in many regards a really succinct example for many doubts expressed by NGOs from development cooperation against the use of transgenic seeds in developing countries. The socio-economic effect for the country seems to have been marginal, because the actual added value took place outside the country and in Costa Rica itself, merely a small number of unqualified jobs were created. The business practices of the international seed breeding companies was questionable, at least in some cases whenever, for instance, testing or propagation was carried out in the open in Costa Rica on lines that were not yet licensed in the countries of origin (of the development of genetically modified plants). This was conducted without carrying out any comprehensive or country-specific risk assessment and with no competent monitoring by the regulatory authorities.

It is difficult to assess the quality of Costa Rican study and development of transgenic varieties, not only with regard to the stages reached but particularly with reference to the adjustment and future potential of the objectives. Overall, there can be seen a necessity for comprehensively strengthening the country's internal capacities for research, development, and risk assessment for transgenic plants. The United Nations Environment Program – Global Environment Facility (UNEP-GEF) procedure has made various deficiencies clear. However, there are visible efforts at improving particularly monitoring and surveillance, not only with the NGOs that are critical of genetic engineering, but also in some of the responsible authorities. Nevertheless, the information conduct of the responsible offices is insufficient, and the participation of civil social groups unsatisfactory, at least from their own point of view.

Chile

In Chile, too, it is still not permitted to cultivate transgenic products for commercial purposes in the country itself, but only for testing and propagating seeds and subsequently exporting them. However, this field of business has now become definitely relevant, also in economic terms, in Chilean farming which is an extremely powerful business, whose size has been increasing particularly strongly since 2005/2006. In the cultivation period 2007/2008 there was seed propagation on over 25 000 hectares, of which more than 80% was maize. Indeed, maize is by far the most important crop in both conventional and transgenic forms (approx 50% of the seed exports in 2007, which in turn represent about 7.5% of the overall value of plant export products). In addition to the production and export of seeds, the import of several transgenic maize and soybean varieties that are licensed in the USA or Europe is permitted for fodder, which is predominantly used in the growing field of poultry, pork and salmon breeding.

The seed producers in Chile include Monsanto, Pioneer/DuPont and Syngenta, which primarily propagate maize, sunflowers and soybeans. In the genetically modified plants cultivated for propagation, the varieties are above all HR and Bt. As in Costa Rica, seed propagation also takes place as a service for foreign firms or research institutes during the development or testing phase. Among the transgenic characteristics, there are some examples of further biotic and abiotic resistance or tolerance and for so-called »plant-made pharmaceuticals«.

The country's own research on transgenic seeds appears to be very diverse. However, it is equipped with very limited personnel and financial resources, is restricted mainly to universities and is still in early stages. Research is conducted to a great extent on country-specific problems on culture plants that are important for Chile, including drought, salinity and cold tolerance, disease and pest resistance and extending the shelf life of fruits for lengthy transport by ship to the country of sale.

Comprehensive genetic engineering legislation still does not exist, but there are a number of pertinent decrees and acts. There is only a labelling requirement on transgenic food components if these were judged to be substantially different, a feature which to date is not true of any licensed transgenic food plant. Larger capacities for an independent risk assessment have not yet been set up. In parliamentary processes, there are various draft bills on biotechnology and biosafety. It is expected that a future law outline on biological safety will not prove to be overly restrictive under the current government. NGOs critical of genetic engineering basically fault the poorly developed legislation, too few monitoring capacities and insufficient readiness to communicate to the public. One can assume that monitoring the safety requirements in the propagation of genetically modified plants is more thorough than in Costa Rica. There is every indication of this due to the greater economic significance of the business area of seed propagation and the high degree of organisation in the Chilean association of seed growers.

In comparison with Brazil and Costa Rica, the social debate may be no less controversial in its basic structure, but it is not as prominent or distinct. Those opposed to the cultivation of transgenic varieties are – as expected – the ecological farmers and mainly the representatives of small-scale farmers and indigenous groups. The conventional agricultural associations are torn between advocating licensing for reasons of efficiency and fearing possible disadvantages in the export of agricultural products if Chilean agriculture is opened up more strongly.

DISCUSSION OF THE CASE STUDY RESULTS: THE POTENTIAL CONTRIBUTION OF TRANSGENIC SEEDS TO SUSTAINABLE DEVELOPMENT

Research and development: problems of capacity and access

Considerable economic power and comprehensive research capacities are necessary to make a successful national, proprietary development of transgenic varieties realistic. Among the sample countries, this is only the case in China, where in addition the authoritarian state permits operations to be guided on an extremely large scale, and this is a favourable factor. In the other countries, research and development are to some extent strongly dominated by international companies (Brazil) or the extent of activities and capacities seems to be restricted (Costa Rica and Chile). Important barriers and hurdles are the patenting of many procedures and products (which moreover are also owned by a few large companies) as well as unclarified regulation in some cases, which makes the prospects for the success of an R&D commitment hard to calculate.

Particularly in small or poor countries, the available capacities in terms of science and infrastructure are insufficient for autonomous agricultural research in general and for genetic engineering development in particular. In these countries it must thus be clarified what kind of cooperation (with private companies, international institutions/organizations, public R&D in industrial countries) is particularly promising and desirable in the search for the best possible solutions for country-specific problems. The participation of smallholder representatives and other social groups has so far been mostly low or hardly developed in the formulation of research requirements and the search for new (technological) agricultural strategies.

Basically, most countries lack a clear and practicable concept for setting in motion a scientific, social and political agreement regarding the aims, strategies and paths to be followed for sustainable agriculture – this is indeed also true for the industrial countries.

Economic results so far: poor data

Due to insufficient data, it is currently impossible to carry out a final evaluation of the size and distribution of profits in terms of business and economics which have been achieved by cultivating transgenic plants in developing and emerging countries. Studies which claim to be able to do this are not backed up scientifically and are based on unstable projections. Even the case studies from China and Brazil could not improve this situation: The studies published to date on the economic results of Bt cotton cultivation in China are, for instance, based on the data from just a few years and just a few hundred hectares (out of an overall acreage of 5.5 million hectares) and demonstrate enormous fluctuations; for Brazil, no publications at all exist on the cultivation results, only estimations. It is undisputed that, particularly in China and India but also in the Philippines and in South Africa, transgenic varieties are predominantly grown by small- and medium-scale businesses. This observation, however, does not permit any conclusions to be drawn with regard to cultivation results or to the size or distribution of profits.

Serious scientific overview studies point out the basic problem that the actual or possible benefit and profit from the use of transgenic seeds is influenced in many ways by regional and operation-specific factors, including the existing or previously used cultivation technique, pest intensity, the strongly fluctuating price of seed, the competitive varieties and many other factors. Of course, by observing individual cases and taking the specific conditions into comprehensive consideration, and by comparing the alternatives in varieties and cultivation techniques, it is possible to quantitatively determine how the cultivation of a specific (transgenic) plant variety has developed under certain conditions within a defined time period and which economic (and ecological) implications arise here. The influence of individual factors, e.g., the characteristic transferred by genetic engineering, on the individual effects and the overall yield will, however, not allow an exact determination in most cases. For this reason, it is not to be expected that economic investigations based on improved methods will be able to substantially defuse the fundamental controversies on the potential of agricultural biotechnology.

Socio-economic aspects and questions of participation

Further socio-economic effects of a widespread use of transgenic varieties can be observed at two levels: in the seed market (including the design of protection systems for intellectual property) and in the circumstances of agricultural structure such as the size of operations and ownership structure. In view of the position of power – to some extent a kind of monopoly – held by the large biotech seed companies in the field of transgenic varieties, which in part comes up against poorly developed, decentralized seed markets, pressing questions arise regarding the options for guiding further development.

Critics of the spread of HR soybean in Brazil, for instance, assume that any possible economic advantage does not benefit the agricultural family businesses and traditional producer communities. These, they say, are increasingly exposed to the danger of marginalisation as the orientation of Brazilian agriculture becomes increasingly strong towards global markets, and this is further fired by the spread of HR soybean. The beneficiaries in agriculture, they maintain, are large farms and cooperatives, and the clear losers are vendors of produce explicitly free of genetic engineering, including the organic farmers whose market is jeopardized by the risk of contamination from transgenic soybean. In addition to this, the dominance of Monsanto's HR soybean can be seen to exert a bad influence on the number on small and medium-sized seed producers in Brazilian soybean cultivation and their range of varieties.

Questions of social participation arise in practically all sub areas of the development and use of transgenic seeds: in the question of the objective and design of the R&D agenda within the countries, the search for and agreement on a concept of sustainability, the distribution of economic advantages and also in the question of handling possible risks. The case studies from Brazil and Costa Rica in particular make it clear that the vigorous controversies in these countries move around the central topics of participation and social compatibility and not the technical, natural scientific issues of biosafety. However, it is not only in the area of research but also with regard to risk regulation that the participation of interest groups outside industry and science remains more of a desired object, but even within the EU it is still highly controversial.

Risks – evaluation and regulation

An assessment of possible risks and of actually observed negative effects with the use of transgenic varieties is crucially dependent on the chosen standards for comparison and the levels of effect considered. This is why both an unqualified risk analysis (i.e., without any comparison to previous or other forms of agricultural practice) and one that is too strongly focused (on effects proven beyond doubt in the natural sciences or agricultural economy) are inappropriate.

In considering Bt varieties as a possible option for plant protection – but not as an option which can be used indefinitely for dealing with the pest problem –, which must be seriously weighed against other options, many of the particular risks expressed in the debate are put into perspective (effect on non-target organisms, other ecotoxicity, resistance problems). At the same time, it must be required that the standard used to compare Bt varieties should not just be conventional practice but that other innovative, knowledge-based options, e.g., from the field of integrated plant protection and organic farming should also taken into consideration.

A risk evaluation of HR varieties seems even more complex since their implementation causes many and indirect kinds of effect on the cultivation technique (reduction in tillage, fuel savings) and on land usage (crop rotations, increasing acreage). These would have to be considered in the framework of a comprehensive risk assessment and evaluation in addition to the direct effects of the herbicides used and saved on humans and the environment and be weighed up against these. To carry out an industry-wide evaluation, it would then be necessary to have a weighting, which legally protected goods (e.g., health, soil fertility, biological diversity, CO_2 emissions, rural development, resource distribution) have priority (which in turn can only be inferred from the developmental aims of a region or a country) and what contribution can be provided here by genetically modified varieties compared with alternative options.

Basically it must be assumed that the overuse of an option, i.e., here the concentration on one single or just a few crops in terms of acreage and crop rotation contravenes the principles of Good Agricultural Practice and in the long run means great problems.

With a view to biological diversity as a superordinated, ecological, legally protected good, two chains of effect of transgenic varieties are considered to be particularly relevant: on the one hand, influencing the diversity of varieties in the country (and other agrobiodiversity) as a result of altered cultivation techniques and developments on the seed markets, and on the other hand the possible influence of any outcrossing into natural or conventional stocks, particularly in so-called centres of diversity. Even if knowledge here is still very restricted, there is broad consensus on the fact that uncontrolled distribution of transgenic varieties should be prevented, and that the measures for this are insufficient in many countries.

In the area of risk regulation, regulation strategies and policies are still considered to be inadequate or completely lacking in many countries. China and Brazil have made comprehensive provisions for handling genetically modified organisms. In Costa Rica and Chile, pertinent draft bills are still in the parliamentary process. The degree of efficiency and comprehensiveness with which the provisions are implemented and monitored in China cannot be assessed reliably, although there would undeniably be enough resources available. The example of Brazil, however, shows that even a developed legislation is of little use if the political and economic balance of power stands opposed to an application.

The example of Brazil also reveals that even if comprehensive scientific, institutional and infrastructural capacities do exist, there can be a dispute over whether and how the country should have its own more in-depth risk assessment of transgenic varieties specific to the country, if these are already licensed in other countries. This issue is the subject of controversial debate in Europe too. Smaller and poor developing countries are often out of their depth with this. For this reason, it would make sense to provide support in the development and processes of decision-making about which aspects should be investigated specifically for the country or region.

Finally, it should be noted that even where social controversy is vigorously conducted on the use of transgenic seeds, there is mostly only poorly developed comprehensive risk communication on the part of the authorities.

PERSPECTIVES FOR ACTION

In terms of perspective, two tasks are particularly significant in dealing with the implementation of transgenic seeds in the framework of developmental cooperation: the (continuing) task of expediting capacities and basic conditions in the field of biosafety and regulation as well as answering the central question of how to better elicit and employ a possible future potential for transgenic cultivation methods than has been the case for developing and emerging countries.

Promoting capacities and normative frameworks in the area of biosafety and regulation

As the project results show, according to strict German or European standards the necessary scientific and political/regulatory preconditions still do not exist in most developing countries or even in any comprehensive form in highly developed emerging countries. This justifies the concentration to date of German developmental cooperation on »capacity building« in the field of biosafety in terms of the Cartagena Protocol or with a view to putting it into practice. Support of this kind seems useful and necessary given that genetically modified plants are being grown on an increasingly large scale and are continuously advancing, in some cases through uncontrolled channels into more and more countries.

Three aspects of the topic biosafety and regulation are (or remain) probably particularly important for the future in developing countries, and are thus remits for intensive cooperation:

> *Improvement of Risk Evaluation and Risk Communication:* With regard to the import and cultivation of transgenic seeds that has been developed, assessed as safe, and first licensed in a different country, the further development of criteria and procedures for decision making would be helpful: which elements from previously conducted safety assessments could be reused and which should be newly investigated specific to the country or region. Here, it seems useful and necessary to include particularly affected social groups. In addition, there must be comprehensive and careful risk communication.
> *Ascertainment and Substantiation of Knowledge of the Threat to Biodiversity Through the Use of Transgenic Varieties:* Although biodiversity is the superordinated legally protected ecological good, knowledge of it is only rudimentary in many ways. The influence on the diversity of the country's varieties (and other agrobiodiversity) as a result of changed cultivation techniques and by developments in the seed markets and possible consequences of the cultivation of genetically modified plants in the centres of diversity (via the outcrossing of transgenic characteristics into related wild varieties or types) still constitute important topics for investigation in which the use of farming knowledge should be accorded a position of prominence.
> *Establishing Functioning Systems of Coexistence, Proof of Origin, and Labelling*: Independent of the use of transgenic varieties, identity preservation (IP) is regarded as a central requirement and challenge for food production as the latter becomes increasingly internationalised and industrialised, and which as supermarketisation progresses is becoming an even stronger factor, directly in the urban centres of developing countries. Germany and the other EU countries can offer comprehensive know-how in procedures for labelling and for proof of origin and in addition have a responsibility as importing and exporting countries. Since global agreement on compulsory standards as set out in the Cartagena Protocol seem to be destined to remain difficult for the foreseeable future, bilateral and voluntary systems and agreements represent an important option.

Going beyond these concrete tasks in the field of biosafety and regulation, it would be an important future task for many countries to achieve a better foundation and framework for risk assessment through basic agreement on the aims, strategies and paths to sustainable agriculture.

Agricultural biotechnology as a future agricultural option?

The debate that flared up in Spring 2008 on the future of global agriculture and the objectives, paths and priorities for the future use of natural resources overall, also put the question of the potential of agricultural biotechnology back on the agenda (especially through reports from the World Bank and the IAASTD). The current report concentrates on the question of the status which transgenic breeding approaches could have for developing and emerging countries in the future and whether it is necessary to re-evaluate agricultural biotechnology in the framework of developmental cooperation in the broadest sense.

Evidence suggests that for the evaluation of the future problem-solving potential of genetic breeding approaches it is *not sufficient to consider existing developments*, since the commercially available transgenic plant varieties as well at least as those at an advanced stage of development only represent a limited section. The study of genetic breeding approaches may be conducted in a decentralized way, even in publicly financed institutions and smaller companies, but the real development of genetically modified plants, by contrast, is conducted predominantly by a few large seed companies. Many of the most significant of these, first and foremost Monsanto, but also Dupont/Pioneer, Syngenta, Bayer CropScience and BASF, are also producers of important agricultural chemicals. In connection with the (literally) exclusive significance of patent-protected procedures in the genetic engineering of plants, it is thus glaringly obvious that the genetically modified plants available on the market represent those that fit best in the portfolio of these companies and *by no means all those which could potentially be successful on the seed markets*. If the development to date continues, it is to be expected that these few large biotech seed companies will continue to dominate to the same extent if not more, since they of course have a primary interest in successful and profitable varieties whose transgenic features fulfil their function for as long as possible for as many users as possible. Diversification under the conditions of the world agricultural market is subject to relatively narrow economic limits so that it cannot realistically be expected that these companies will of their own accord develop a variety specifically designed, for instance, for poor developing countries or regions.

In addition to the problems of companies' own interests and patent protection, many proponents of agricultural biotechnology regard other important reasons for the low number of development approaches specific to developing countries to lie in the regulations – which they see as overly strict – and campaigns of the opponents. But independent of the dominant factors in question, it is absolutely certain that the development of a marketable, transgenic variety is lengthy, elaborate, and costly and can thus not be achieved by public institutions, in any case not in smaller countries or by smaller companies. No transgenic variety developments have yet emerged even from IARC activities. However, it cannot be seriously deduced from the non-existence of adapted varieties that genetic engineering in plant breeding is fundamentally unsuitable for developing countries.

Overall, even 25 years after the development of the first transgenic plant and after 12 years of widespread use of transgenic seeds, there is still great uncertainty:

> Does genetic engineering harbour dormant potential for sustainable agriculture in both industrial and developing countries?
> Is it even possible to elicit this potential, particularly when one considers the basic economic and legal conditions?
> Are there other options which are more promising in terms of ecological and social success and which are thus to be preferred?

As with other technology applications too, questions such as these are often not unambiguous and cannot be answered conclusively. In addition, the development and application of transgenic varieties take place in the context of such a complex, multifactorial framework of effects that any analysis of the consequences that is orientated to causality can have only little explanatory value. The complexity of the ecological, economic and social effects and interactions results in a technology-fixated evaluation (»Chances and Risks of Agricultural Biotechnology«) being incapable of representing the key to an overarching consensus in view of the great conflicts of interests and objectives held by different social groups. The project results ultimately make clear that ecological and health effects are not so much at the centre of the controversies over the use of transgenic seeds but in the end rather the socio-economic effects and questions of social participation and balance of interests.

Overall this argues strongly in favour of steering towards a solution-orientated approach in search for potential future agricultural technologies and cultivation methods. With a view to transgenic plants, this means examining genetic engineering options without a predetermined result. Thus, with reference to the challenges of climate change and problems of water supply or other stress factors, it would be appropriate to first inquire into the existing and foreseeable agricultural challenges overall and only then into the means of possibly or necessarily adjusting cultivation methods. The contribution of plant breeding will be encountered here in some parts of the question, and only then can options for agricultural biotechnology be examined in a sensible way. The same is true for the problem of micronutrient deficits (cf. the example of Golden Rice) and many other examples. Of course, this does not absolve us from the obligation to consider dimensions specific to the technology (e.g., the increased requirements on measures to guarantee biosafety) – this must form a part of the consideration process.

The current framework conditions are probably better than they have been for a long time for serious attempts at achieving consensus. The most recent developments on the global markets for agricultural products, for food, bioenergy and other sustainable resources have triggered a new dynamism and urgency with regard to the question of how global agriculture can be organized and run in a more sustainable fashion in the future than it has been in the past. The mobilisation of significantly larger funds for studying the scientific and technological options than in the past has at least been announced, and we can expect this to take place. In the light of these trends, a renewed attempt to find a pragmatic consensus (or a partial one) concerning agricultural biotechnology and its role in developmental cooperation does not seem doomed to failure from the start.

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