The Environmental Impact of Agricultural Biotechnology

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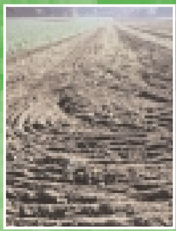
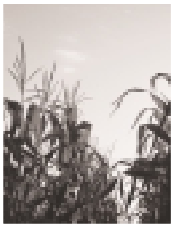


Agricultural Biotechnology in Europe

Promoting an open and informed dialogue



The Environmental Impact of Agricultural Biotechnology

Introduction

Modern biotechnology is an important new tool in the development of sustainable agricultural systems. Despite its extremely rapid uptake in North America, Argentina and now, increasingly, China, India and parts of Africa, a variety of factors have effectively put a hold on commercial planting in Europe. The two primary areas of concern which are expressed are the potential negative effect on the environment and fears about food safety. Environmental impact will be dealt with in this, the third in this series of reports issued by ABE; food safety considerations will be covered in a later one.

It would be easy to point to the vast area of land on which GM seed has already been sown over the past few years, and to the lack of any reported negative effects on the environment. However, the data largely relates to the prairies of the American Mid-West and Canada, effectively separated from areas of wilderness. In Europe, farmland exists alongside woodland, moorland and urban areas; indeed in many countries the major part of the landscape is entirely shaped by farming practices. In this context, it is right that we should think very carefully when making any significant changes to agricultural systems.

This report therefore covers the main criticisms levelled at the use of modern biotechnology in farming, and attempts to answer them factually and honestly. Our main conclusions are:

- All farming systems have an inevitable impact on the environment. The use of genetic modification is one factor among many.
- Modern biotechnology has already delivered very real environmental benefits in other countries, and it has the potential to make a similar contribution in Europe.
- Cross pollination between some biotech and conventional crops can occur at low levels under some circumstances. However, for crops currently approved or under trial, this will have no detrimental effect on the environment.
- Pollination of weeds by GM crops can also occur in very limited circumstances, and again there will be no environmental consequences for current crops.
- Potential environmental effects are assessed in depth by the authorities before new crops are grown outdoors, even on a trial basis.

We hope you agree with our conclusions: whether you do or not, we look forward to hearing your own views.

Agriculture and the environment

In an increasingly sophisticated and technologically-advanced society, many people set great store by "naturalness". In its simplest form, this mindset equates "natural" with "good" and "man-made" with "bad". A little thought, of course, makes us realise that things are not so simple. Hurricanes, floods and cholera are definitely natural, but pretty bad news; houses, boats and antibiotics are man-made, but can protect us from the ravages of nature.

We also have a less than clear idea of what really is natural. We regard the countryside as natural, and yet, apart from wilderness areas, it is almost entirely shaped by Man. Before the introduction of farming, most of northern Europe would have been covered by forest, and the small human population led a hunter/gatherer existence. It was the introduction of farming - the realisation that land could be cleared and sown with seeds, and that certain animals could be domesticated - which allowed Man to live in stable settlements and gave time for civilisations to develop.

By any reckoning, the birth of farming was one of the most important events in the development of Mankind; arguably the most important. However, it was also the least natural: it led to the clearance of vast areas of forest, to the ploughing of land and hence the destruction of ecosystems. Nevertheless, it happened, and was crucial to the evolution of modern civilisations and societies. And, unless anyone is advocating a return to a hunter/gatherer existence, supporting only a tiny fraction of the current population, modern agriculture has to be sustained. All agriculture has a major effect on the environment: we have to choose exactly what that effect will be. The use of biotechnology is one of the many factors in the overall equation.

So, to summarise:

- Farming of any type has an impact on the environment
- We can decide the nature of the impact by the systems we use

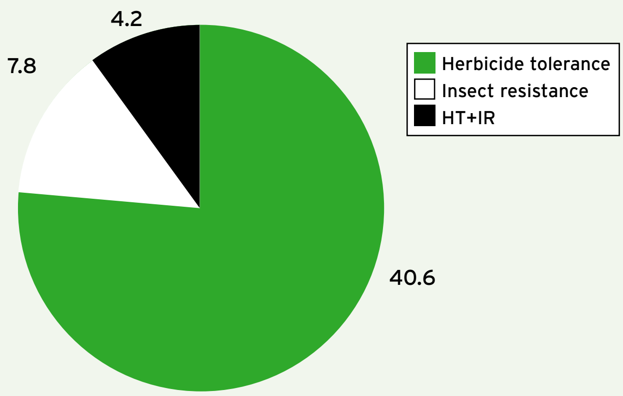
Current applications of modern biotechnology in agriculture

To date, there are relatively few commercialised applications, the main ones being:

- Herbicide tolerant crops - primarily soya, oilseed rape and maize varieties, each tolerant to a single broad spectrum herbicide.
- Insect resistant crops - principally maize and cotton producing a protein that controls certain insect species.

Figure 1 summarises the global situation in 2001.

Figure 1: Breakdown of global GM crop plantings. Total global plantings in 2001 = 52.6 million hectares



(Source: ISAAA Briefing Number 24; 2002)

In addition, there have been a number of other developments which, for a variety of reasons, are not in commercial cultivation. This list includes potatoes resistant to viruses and Colorado beetle, tomatoes which could ripen fully without softening, and herbicide-tolerant sugar beet.

The only biotech crop grown commercially in the EU at present is insect resistant maize, in Spain (together with a few hundred hectares of the same crop in Germany). In 2001, approximately 25,000 hectares were grown, some 5% of the total Spanish maize crop. This so-called "Bt" variety has been modified to produce a protein naturally secreted by a common soil bacterium. This protein is harmless to plants, all vertebrates and the great majority of invertebrates, but interferes with the digestive process in certain species of insect. The target pest in the case of maize is the European corn borer, which causes significant yield losses. The bacterium itself is often used as an insecticide, particularly by organic farmers. Insect resistant maize is likely to be of benefit also to other European farmers, where insect infestation can lead to significant yield loss.

The other candidate crops for further commercial development in Europe in the short term are maize, oilseed rape and sugar- and fodder-beet tolerant to herbicides. It is these applications and their environmental effects which we will focus on in the next sections.

Herbicide tolerance and weed management

Herbicide tolerance in plants is not something new, achieved just by the use of biotechnology. Most plants are resistant to a number of common herbicides; and some weeds are almost impossible to control effectively via current chemical treatments. What is new is the ability to create a degree of tolerance to broad spectrum herbicides - in particular glyphosate and glufosinate - which will control most other green plants.

The reason for doing this is to give the farmer simpler, more effective weed control, often also giving environmental benefits. The two herbicides mentioned are particularly useful for weed clearance, since they interfere with essential processes in the cells of most plants. At the same time, they have minimal direct impact on animal life, and are not persistent. They are therefore both highly effective and amongst the safest of agrochemicals to use. Unfortunately, they are equally effective against crop plants.

Adding copies of genes from bacteria, which resist these compounds, to conventional crop varieties - soya, maize, beet etc - results in crops having the advantage that they can be sprayed with a specific herbicide and still develop normally. This has multiple advantages to the farmer, including:

- Excellent weed control and hence high crop yields
- Flexibility - possible to control weeds later in the growing cycle without reducing crop yield
- Reduced numbers of sprays in a season
- Reduced fuel use (because of less spraying)
- Reduced soil compaction (because of less need to go on the land to spray)
- Use of low-toxicity compounds which do not remain active in the soil
- The ability to use no-till or conservation-till systems, with consequent benefits to soil structure and organisms

Of course, not all these benefits necessarily accrue in each case, but the combination has been sufficient to result in an unprecedentedly rapid uptake of the new varieties by North American farmers.

In a recent review (Phipps and Park; 2002), it was estimated that, if 50% of the maize, oilseed rape, sugar beet and cotton grown in Europe used current GM traits, 7.5 million fewer hectares would need to be sprayed. This would save over 20 million litres of diesel fuel, and reduce atmospheric emissions of carbon dioxide by 73,000 tonnes each year, and is additional to the obvious savings in chemicals.

Gene flow and its consequences

There has been considerable discussion about the likelihood of unplanned gene transfer from GM crops and its consequences.

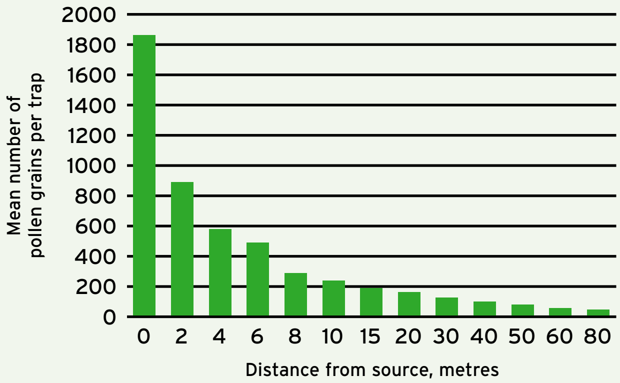
A report was recently issued summarising first outputs from a joint European Science Foundation/European Environment Agency project (EEA Environmental Issue Report number 28; 2002). We will refer to this and other sources in this section.

In the case of plants, which generally reproduce sexually, there are two basic conditions which have to be met before such gene flow is possible:

1. pollen must be transferred from one plant to the pollen receptors of another at the appropriate time
2. the plants must be from the same species or from two species which are sexually compatible

Figure 2 shows the typical pattern of spread of pollen by wind: note the rapid drop-off with distance, and long, low-level tail. This represents the maximum available pollen; in practice only a small proportion of it is likely to reach a sexually compatible plant which is in flower and has not already been pollinated by adjacent plants.

Figure 2: Spread of pollen by wind



(Source: M D Hayward et al)

The other factor which has to be taken into account is insect pollination. Although there is a rapid drop-off of transmitted pollen spread only by the wind, bees and other insects are capable of carrying pollen to receptor plants over distances of several kilometres. So, there is the possibility of a very low level of gene transfer over a wide area. This very low level background of cross pollination has never presented a problem in the production of high purity seed of crop varieties season after season.

There are only limited opportunities for gene flow between plants to occur in practice. To take three examples, sugarbeet, oilseed rape and maize, all relevant to European agriculture:

- **Sugarbeet** is naturally outcrossing, that is individual plants are fertilised by other plants. This suggests that there should be considerable scope for gene transfer to other species to occur. However, sugarbeet has only one wild relative - sea beet - in the areas in which it is grown. Even more importantly, it is a biennial crop harvested after its first year of growth; flowering occurs only in the second year. So, there is actually no potential for cross-pollination, with the exception of 1% or less of "bolters" (plants flowering in their first season) which occurs with any beet crop. It is in any case good practice for farmers to remove bolters on a regular basis, before they set seed, to minimise the potential weed beet problem the following season.

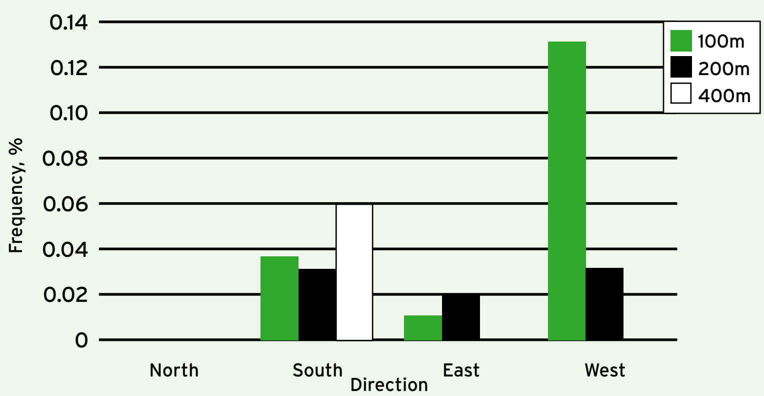
  Thus, in practice, gene flow is not an issue for sugarbeet.

- **Oilseed rape** has different characteristics. First, it has a lower tendency to outcross, being approximately 70% self-pollinating. It is, however, an annual crop. The flowers produce considerable quantities of pollen, but this travels quite short distances. In fact, the accepted separation distance between two conventional varieties of rape to give less than 1% cross pollination is only 1.5 metres. However, it does have natural wild relatives (for example, wild turnip and wild mustard). So, in this case, transfer of genes to certain weeds is a possibility.

  The EEA report describes oilseed rape as a "high risk crop for pollen-mediated gene flow from crop to crop and from crop to wild relatives". This has to be interpreted as "high risk of a low level of gene flow". See, for example, figure 3, which shows the very low levels of actual pollination under field conditions. Note that "bait" plants in this experiment can only be pollinated by the GM crop (they produce none of their own pollen): this represents a "worst case" scenario. You will see also the effect of weather conditions: pollen flow varies considerably with wind direction.

Figure 3 Pollination of fully fertile, male-sterile bait plants by GM herbicide tolerant oilseed rape as a function of distance and direction (Source: Simpson, unpublished)

Figure 3: Percentage of Herbicide Tolerant rape seed harvested from bait plants, by distance from GM crop



(Source: Simpson, unpublished)

- **Maize** is a typical outcrossing plant, almost completely wind-pollinated. However, since this crop is a native of the Americas, it has no wild relatives in Europe, and so no possibility of transferring genes to weeds. Also, despite the large quantities of pollen produced by each plant, separation distances of only 200 metres between varieties are sufficient to achieve high purity in seed production (EEA report).

Cross-pollination between varieties of some crops and between certain crops and their wild relatives happens naturally at a low level all the time. So, why should it worry us in the case of GM crops? The simple answer is that it depends on the genetic trait which is being transmitted. This also means that, if a particular trait were to be a cause for concern for any reason, this concern would be as high if the tolerance was a result of "conventional" breeding.

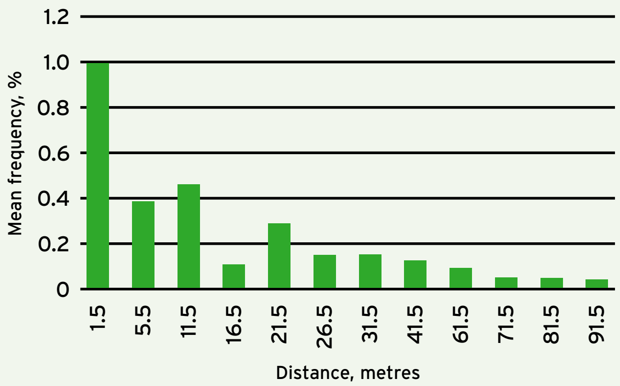
Practical consequences of gene flow: an example

Let's look at the consequences of growing herbicide-tolerant rape on a large scale. First, there would be some low-level cross-pollination if it is grown close to compatible plants with no precautions being taken. Secondly, however, there would be no significant environmental effect, either positive or negative.

Take the cases of cross-pollinated of rape with another variety, and with wild relatives:

- **Pollination of another rape crop would be at a low level, even if the two fields were adjacent.** The result would be a low level of the conventional crop acquiring a specific resistance: less than 1% at the field margin, and a much lower level for the field in total (see figure 4 for a real example). If the farmer wanted to treat the field with this specific herbicide the following season, any resistant rape "volunteers" (unwanted plants which germinate from seeds of the previous crop) would survive. At worst, this is a nuisance for the farmer, who needs to treat these with another herbicide or remove them mechanically or manually. In practice, these would easily be eliminated using the conventional treatment for the next crop in the rotation: rape is normally grown as part of a rotation with cereals, for which quite different herbicides are used.

Figure 4: Mean percentage herbicide tolerant seed in conventional winter oilseed rape variety by distance from GM crop



(Source: EEA report quoting Simpson, unpublished data)

- **Although rape has a number of wild relatives, cross fertilisation does not necessarily occur.** For example, a five-year study undertaken by a consortium of research institutes in France (coordinated by CETIOM: Centre Technique Interprofessionel des Oléagineux Métropolitains, 2000) found no crossing of herbicide tolerant rape with wild mustard species either in the test plots or nearby. The vast majority of any cross-pollinated wild relatives which might arise in some circumstances would be outside the field boundary, and would remain untreated with any herbicide. They would then have exactly the same life cycle as the other weeds: the tolerance would not give the plants any competitive advantage, and it is very unlikely that the gene would be passed on for more than a few generations.

  We all know that rape volunteers occur outside field margins: their bright yellow flowers are unmistakable in summer. However, as with all cultivated plants, they are rather uncompetitive in the wild, and normally die out after two seasons at most. Again, the cross-pollination gives them no evolutionary advantage, and they do not pass on herbicide-tolerance into the wider gene pool. A ten year study by researchers from Imperial College London (Crawley et al) of conventional and biotech crops in natural habitats found, as expected, no increase in competitiveness for the GM varieties. After four years, there were no surviving plants of rape, maize or beet. Only a few potato plants survived after ten years, and none of these was transgenic.

Of course, these arguments are not necessarily valid for all GM crops. It is quite possible to think of a trait which we would not want to see transferred. However, that is precisely the sort of question which is asked by the regulatory authorities, who would not allow such a crop to be grown in the open without stringent safeguards.

Actually, there are already "conventional" crops grown for which cross-pollination is to be avoided. The best example is probably high erucic acid rape (HEAR), whose oil is not for human consumption, but which has industrial uses. The normal oilseed rape (OSR) which we use for food is derived from HEAR and the two are easily cross-pollinated. However, careful control of cultivation enables both HEAR and OSR to be grown in the same country with no problems.

As the science develops, modified crops will begin to be produced which have no ability to transfer their genes to related species, for example because the genes do not appear in the pollen. This is likely to be absolutely vital if one day crops producing vaccines or other valuable products are to be grown in open fields.

Effects on biodiversity

Biodiversity is a term which is often used rather loosely. Strictly, it covers the number of species of all forms of life in a given area, including all bacteria, invertebrates, reptiles, mammals, birds and plant-life. However, it is often used in the sense of total numbers of visible animal, bird or plant life and, in particular, sometimes in terms of birds, butterflies and other visually attractive wildlife.

As we have seen, agriculture itself - of any form - has a major impact on landscape and species. Starting with virgin land, conversion to agriculture will reduce or eliminate some species: tree-dwelling birds and a number of plant species adapted to growing in the shade of trees, for example. However, it will also provide new ecological niches for other species to occupy: farmland birds such as skylarks and lapwings would be typical examples.

If a particular area is forested, cutting down some of the trees and growing crops on the cleared land may actually increase biodiversity over the total area, by providing habitats for different birds and animals. Complete clearing of the forest, on the other hand, will eliminate a large number of species from the area, but may or may not reduce overall biodiversity. As in everything, it's a question of balance, and it's up to society to decide what is acceptable.

At first sight, agricultural biotechnology doesn't seem to have a lot to do with biodiversity, but there are some critical comments which are sometimes heard, including:

- "Crop biotechnology will lead to further intensification and industrialisation of farming, and inevitably reduce biodiversity."
- "Widespread use of GM crops will give rise to vast areas of monoculture, essentially sterile apart from the crop itself, and highly vulnerable to diseases or pests."
- "Cross-fertilisation of existing varieties and landraces will eliminate genetic diversity."

Let's look at each of these in turn:

1. **Increased intensification of agriculture.** There is a balance to be struck between organic and similar systems, which require more land to be farmed to produce an equivalent output, and highly intensive systems which aim to eliminate all weeds and pests and produce the maximum yield possible. In practice, many European farmers have adopted systems such as Integrated Farm Management, using reduced inputs and getting high but not necessarily maximum yields. Such systems are capable of giving biodiversity results comparable to those from organic agriculture (see for example, the Boarded Barns Farm study).

   In practice, it is not intensiveness which has the maximum negative effect on wildlife, but certain practices such as winter sowing of crops and elimination of hedgerows. As the Common Agricultural Policy (CAP) is reformed and farmers are rewarded for managing the countryside as much as for producing food, such practices are likely to change (see, for the example, the UK Policy Commission on the Future of Farming and Food: Farming and Food - a sustainable future; January 2002).

   There is no reason why introducing GM varieties will be bad for biodiversity. In the case of herbicide tolerance, farmers are likely to use the increased flexibility to spray only when and where necessary, often spraying less and later. This will have a beneficial effect on the populations of non-target insects, and provide more food for birds and animals which feed on them. Later spraying of weeds will leave more seeds for other birds to feed on.

For a given amount of food produced, intensive agriculture uses less land, allowing woodland, field margins and other areas as habitats for more plant and animal species.

2. **Monocultures,** large areas covered by a single agricultural crop, occur because farmers try to maximise the yield of their most profitable crop. This is particularly true when farm incomes are low and payments for countryside management and other non-productive activities are not sufficient to offset production subsidies. Modern biotechnology has no influence over agricultural practices as such: in Europe, the CAP has the major effect.

3. **Genetic diversity** It is estimated that there are some 7000 crop species cultivated globally, yet just 30 of these account for over 90% of calorie intake. In a given region or country, the range of crops cultivated to a significant extent will be even more limited. For each of the major crops - wheat, rice and maize being the top three worldwide - local genetic diversity has continued to narrow as breeders have selected the best parent stock for further crossing. The techniques of genetic modification have no further influence on this: they just introduce one or two extra genes into the tens of thousands in the existing genetic background.

   The truth of this is clear when we look at the case of herbicide-tolerant soyabeans, currently the world's largest GM crop. The great majority of these originate from a single transformation event, giving tolerance to a single weedkiller called glyphosate. However, this trait has now been incorporated by conventional breeding into literally hundreds of individual varieties, tailored for a range of different growing conditions. Indeed, other techniques of modern biotechnology - particularly marker-assisted breeding - will allow valuable individual traits from low-yielding traditional varieties to be incorporated into the best modern seed. Overall, biotechnology seems likely to increase the genetic diversity of our major crops.

Coexistence with organic agriculture

The current standards set by the organic food industry do not allow the use of modern biotechnology in farming practices. European regulations do not stipulate the quality of the final produce, only the rules which must be followed in production. For example, residues of pesticides not approved for organic use are regularly detected on organic vegetables: this is accepted because the spraying was carried out on neighbouring, non-organic farms. However, in the case of modern biotechnology, the interpretation by some approval bodies is that organic produce must contain no detectable trace of transgenic protein or DNA. The normally-accepted EU standard of up to 1% presence of GM material is not considered good enough: total absence is demanded. Some in the organic movement think that GM crops must be separated from organic ones by several kilometres.

In reality, there is no reason why genetically modified seeds should not be compatible with organic farming practices. Disease resistant varieties for example, which would eliminate the need for certain classes of crop protection agents, would be compatible with the organic philosophy of reduced chemical inputs. However, realising this compatibility seems to be some way distant at this stage.

Other applications of crop biotechnology

In other parts of the world, insect resistant (so-called Bt) varieties of maize and cotton are widely grown, and there is also a significant area of Bt maize in Spain. Also important in Europe would be resistance to fungal and other diseases. In some countries, particularly in the tropics, there are problems with acidic, high-aluminium soils, or saline soils (often the result of long-term irrigation).

These and other problems, including drought tolerance (already being assessed for maize in France), could in principle be tackled by appropriate use of modern biotechnology. Each, despite its undoubted benefits, would have some environmental impact, and the acceptability or otherwise of this would have to be appropriately assessed. The EU regulatory regime would ensure the full, detailed and independent assessment of these impacts before plantings took place, and monitoring of the crops being grown.

Assuring environmental safety: the EU regulatory system

Although many hundreds of outdoor trials have taken place, crops produced with modern biotechnology are not yet grown commercially in any EU Member States apart from Spain and Germany. In Spain, 25,000 hectares of GM maize were grown in 2001.

All plantings of biotech seed are tightly regulated under the EU Deliberate Release directive 90/220, which will be replaced in all Member States by the even more restrictive directive 2001/18 by October 2002. Each trial planting must be approved by the relevant national authority, and is subject to detailed conditions in terms of management, separation distance and disposal.

For a transformation "event" (the technical description of the specific change to the plant's genetic makeup) to be approved for commercialisation, an exhaustive assessment of safety data is made by one national authority before a recommendation is made. Each other Member State (and the European Commission) has the opportunity to comment and ask for further information before a decision is finally made by the European Union. That decision then applies to the whole EU, although individual members have the right to impose further restrictions if justified.

Despite the extreme stringency of this system, there is not the political will in all Member States to make it work, hence the de facto moratorium on new approvals. This and other issues will be considered in a later report in this series covering the regulatory scene.

The experience outside Europe

In contrast to the situation in Europe, US, Canadian, Chinese and Argentinean farmers in particular have been growing GM crops - soya, maize, oilseed rape and cotton - on a large scale for several years. Of course, their countryside is different, and their potential environmental issues different. These have been assessed in a rigorous way, and strict management regimes imposed for certain crops to avoid potential problems. Nevertheless, there have been no proven instances of environmental harm, and there are real environmental benefits accruing.

In particular:

- Soyabean farmers are able to spray less to control weeds when they grow herbicide tolerant varieties (a move from spraying "just-in-case" to "as and when required"). Not only is this a financial benefit, but fewer tractor passes means less fuel use and less soil compaction. In addition, this technology allows soyabean farmers to have the benefits of no-till or conservation-till cultivation systems. Both these avoid the use of deep ploughing, with significant benefits to soil structure and numbers of invertebrates. The combined fuel saving are high and the benefit to the soil structure very evident.
- High quality maize in high yield is obtained by use of insect resistant varieties. The plants themselves are environmentally safe, and only affect the target pest. Beneficial insects are therefore unharmed. As with soyabeans, no-till cultivation systems may be used: for conventional varieties, ploughing is normally necessary to dislodge corn borer larvae to kill them by exposure to winter weather.
- Use of insect-resistant cotton varieties has led to a major reduction in spraying, while increasing yield. Because of drastic yield loss when attacked by pests such as the bollworm, conventional cotton is the most intensively sprayed crop in the world: introduction of pest-resistant Bt varieties is estimated to have reduced the total world use of insecticides (for all crops) by 14% (Phipps and Park; Journal of Animal and Feed Science; 2002). As well as the USA, this technology is now in use in China, Mexico, Australia, Argentina and South Africa.

  In the Makhathini Flats area of KwaZulu-Natal, in South Africa, roughly 5000 hectares of cotton is grown by small farmers, typically in 3-10 hectare plots. Farmers who grew Bt cotton in the 1998 and 1999 seasons saw yield increases of 20-100% and a reduction of 5-8 sprays per season. Each spray can require a walk of several kilometres to fetch water, and a 20 km walk per hectare for manual spraying (Gregory et al; Adoption of Bt cotton by small-scale farmers in South Africa; Pesticide Outlook 2002). This technology can give major improvements to the quality of life of small farmers, as well as benefiting the environment.

Conclusions

- All farming systems have an inevitable impact on the environment. The use of genetic modification is one factor among many, and must be assessed in this context.
- Very real environmental benefits are already being delivered by the use of modern biotechnology in agriculture, and its continued development should play a significant part in sustainable farming systems.
- Cross pollination between some GM and non-GM crops can occur at low levels under some circumstances. However, any transfer of transgenic traits from crops currently approved or under trial will have no detrimental effect on the pollinated plants or the environment. Cross pollination is manageable and well controlled.
- Pollination of weeds by GM crops can also occur in very limited circumstances, and again there will be no environmental consequences for crops currently under consideration.
- Potential environmental effects are assessed in depth by the statutory authorities before transgenic crops are grown outdoors, even on a trial basis.

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Who we are

The companies involved with the development of agricultural biotechnology believe strongly that biotechnology has the potential to enrich our lives in many ways. We recognise, however, that the introduction of genetically modified crops and foods has raised concerns in many European countries. Our industry has an ongoing commitment to scientific research and testing, and to ensuring that products are developed and commercialised in a responsible and safe manner. We also recognise that the success of any new technology in Europe needs to be based on respect for people's viewpoints. The biotechnology industry believes that consumers should be as informed as possible. The agricultural biotechnology industry is therefore working with various organisations across Europe to improve transparency and to foster a useful dialogue on agricultural biotechnology. Our efforts focus on broad and serious communication to a range of audiences - media, NGOs, policy-makers, retailers and others - with the aim of listening to and respectfully addressing the concerns of European citizens as well as making information available about our industry and this technology.

The following companies are participating in this effort:

Aventis CropScience
BASF
Bayer
Dow Agrosciences
DuPont
Monsanto
Syngenta

Our aim is to increase the dissemination of information and contribute to an informed debate about crop biotechnology. If you are interested in receiving more information about agricultural biotechnology, please contact; Peter Wynne Davies at:

info@ABEurope.info or consult the ABE website at www.ABEurope.info

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