Centre for Agricultural Strategy

Biotechnologies in agriculture and food- coming to the market

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2 Arable crops - scientific developments and market prospects

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NEED FOR NEW TECHNOLOGY

Any discussion of a new technology should consider why that technology is needed. There are three major answers: one the need to keep the United Kingdom (UK) arable and horticultural crop growers competitive in an increasingly competitive world market; two, the need to provide food for an increasing world population which is likely to want increasing living standards, particularly in Asia; and three, the need for agricultural production to be sustainable and environmentally friendly.

These three key issues and recognition of the decline in the rate of increase of crop yields, limitations of land and water resources, and the pressures of pests and diseases, also featured prominently in Oliver Doubleday's 'wish list' of his expectations from the application of biotechnology (Doubleday, 1996).

WHAT IS BIOTECHNOLOGY?

Biotechnology is one of the oldest of technologies and is the basis of many of the things we take for granted in our food. It was mechanised very early on, for example, in the production of wine, bread and cheese. However, it is not this familiar technology which is now associated with 'biotechnology' but rather the technology that arises out of the advances in molecular genetics and in cell biology over the last twenty years. This technology can be referred to as 'New Biotechnology'. It depends on the ability to identify, isolate, and manipulate the genetic information encoded in the organism's DNA (deoxyribonucleic acid) and on new techniques in cell biology. It is this new biotechnology that gives rise to the understandable concerns of the public.

WHAT IS NEW BIOTECHNOLOGY?

It is based on the discovery of enzymes in micro-organisms that can recognise and cut up or join together DNA in a specific manner. Parallel with these advances, research in cell biology has developed ways in which cells can be cultured and, for plant cells, whole plants can be generated. This has led to the ability to insert new genes into whole organisms in new combinations. This process of recombination has led to the use of the term recombinant DNA (or rDNA) technology to describe it. Discoveries that allow the information encoded in the DNA to be 'read' have stimulated ambitious projects to 'read' all of the information encoded in a plant nucleus. It is expected that we will know the complete sequence of DNA in rice and *Arabidopsis* within five years. It is important to understand that biotechnology is not a *product* but one of many technologies that may be used in the *production* of products. In fact, it is not always possible to tell if a product was produced using biotechnology.

The other aspect is that the product that impacts the market may be knowledge rather than an article. This is because of the tremendous discriminatory power of the technology. Because it is possible to recognise even small changes in the sequence of DNA between individuals it can be used to identify the presence of species or individuals: rDNA technology and monoclonal antibodies have led to great advances in diagnostics.

WHAT CAN BIOTECHNOLOGY DO?

The new biotechnology can bring new products into agriculture. It can also allow old products to be produced in new ways: perhaps the most widespread is the production of vegetarian cheese which is widespread in UK supermarkets. This is made using the enzyme chymosin (rennet) produced from yeast rather than a calf's stomach. The gene for the enzyme was cloned and introduced into yeast and then produced in large amounts by fermentation. The new biotechnology can also add new properties to old products, for example crops with built-in insecticides, herbicide-tolerant crops, tomatoes with modified ripening, and modified biological control organisms. By introducing new genes into crop plants they can acquire new traits - these are discussed below.

The technology opens up the possibility of using organisms to produce a wide range of products that have traditionally been produced in other ways. Plants are potentially very attractive producers of high-volume products that are now produced by fermentation or cell culture and which require large inputs of energy. Because plants are cheap to grow and provide their own energy they have the potential to be important processing factories.

The ability to isolate genes that encode important target sites for crop protection chemicals allows these to be produced in large amounts for study. Advances in the technology may be expected to improve the selection of crop protection agents in the long term.

rDNA technology has also led to the development of tools to help plant breeders. Plant breeding is itself a type of recombinant technology in which sexually compatible individuals are crossed and new individuals chosen from the offspring. During this process the DNA of the two parents recombines in an uncontrolled way. Previously, the plant breeder was forced to choose from large numbers of individuals from which he could only infer what they had inherited from each parent. The use of new genetic-marker technology allows the breeder to follow much more closely the recombination events in the offspring of crosses.

IMPACT ON ARABLE FARMING

I would now like to turn to the impact that this new technology might have on the arable farmer in the UK. The most important advance will probably be the availability of rDNA crops. I have divided these into three categories because I think they will have different effects on the farmer. There will be benefits for the farmers themselves (disease and insect control), benefits for the consumer (food products such as the tomato purée), and there will be industrial products (pharmaceuticals and lignin-free fibres).

The technology may also have effects on the use of biological-control organisms in agriculture, but I remain to be convinced that they will make a widespread impact on agriculture. Any improvements in crop protection chemicals due to the use of the technology will flow on to the farm in the normal way. However, the ability to diagnose the presence of pests and diseases in the field may be of considerable importance in influencing farming practice.

Progress in plant biotechnology has been extremely rapid despite the fact that many people have felt the technology was oversold. To go from the first transformed plants to products in the shops in just 12 years (see Figure 1) is phenomenal, given that it takes 7 to 10 years to get a new variety or crop protection chemical on the market. The technology is now usable on almost all important crop species and a wide range of new traits have been introduced into plants.

Figure 1
Progress in plant transformation

- 1983
  - First transformed plant (tobacco)

- 1996
  - All major crops transformed (wheat, rice, maize, potatoes, barley, soyabeans)
  - All major vegetable crops transformed
  - Many trees transformed (apples, poplars, bananas)
  - Commercial growing of transformed crops

rDNA CROPS

Figure 2 shows some of the crops that have been developed and which have been approved for release and commercial sale in the United States (US) and/or Canada, most, if not all, of which can be expected to be on sale and grown commercially in 1996. In contrast, as of the end of February 1996, only two crops have been cleared for sale in Europe. This is not because applications for clearance have not been made to the European authorities but due to the fact that the procedure is much more drawn out. Whereas the recent transgenic maize hybrids have been cleared in the US within a year, companies have been waiting over 18 months for clearance of products in Europe.

Figure 2
Approved for sale

- **In USA and/or Canada**
  - Flavr Savr® tomato
  - Bt cotton
  - Bt maize
  - Bt potato
  - Herbicide-tolerant canola, soyabeans, cotton
  - Virus-resistant squash
  - Hybrid oilseed rape

- **In Europe**
  - Bromoxynil-tolerant tobacco
  - Hybrid oilseed rape

In contrast, the UK authorities have cleared several food products for use in the UK including the oil from four different types of transgenic oilseed rape. This means that the products of rDNA crops are potentially available to consumers in advance of our farmers being able to grow them.

Given that rDNA crops will eventually be cleared in Europe, what will be the effects on farming and farmers? In the case where the traits lead to benefits for the farmers it is likely that the crops will be more profitable and easier to grow. Despite all the publicity in newspapers farmers will not be trapped into growing crops that do not make commercial sense for them. No commercial company can expect to make a business if there is not a sharing of the benefit with the farmer. If the genetic remedies are robust then the consistency of yield will be higher. Since the technology will come neatly packaged within a seed, there will be no need for major changes in farming practices.

In cases where the traits incorporated are for the benefit of processors, end consumers or industrial uses, some arrangement will have to be made to attract the farmers to grow those crops. This may be in the form of premiums, such as are currently used to promote the growth of malting barleys or breadmaking wheats. An alternative is to contract out the seed to the farmer to grow in return for a guaranteed market. This is likely to be the case where the seed has a very high value and the owner of the technology wishes to retain ownership and control of that technology. Eventually, contract farming will increase and may limit the freedom and options open to farmers.

In both cases, the range of crops grown on the farm will increase and crops of the same species may have very different properties. It will be important for the farmer to keep these different varieties separate. For example, contamination due to persistence of the seed in the soil of subsequent crops with herbicide-tolerant seed may cause problems. More serious would be contamination of special food crops for oil with high-erucic-acid rape. I would therefore see a need for very careful management of a more complex series of crops.

Diagnostics in agriculture will also increase the complexity of farming. They will increase both the need for technology and the amount of information available. Information, if it is to be useful, has to be translated into decisions. In turn, these decisions have to bring benefit or to be mandatory. Some of the information that can be translated into benefits through increased efficiency and precision may be incorporated for those reasons. Other drivers may be the stipulations on pesticide use enforced by regulations or handed down by the buyers of the produce. It is also possible to foresee in certain countries that it may be necessary to demonstrate a need for crop protection chemicals before they can be used.

BARRIERS TO SUCCESS

I turn now to whether, or the extent to which, Oliver Doubleday will achieve his 'wish-list' (Doubleday, 1996). Although the technology works and has many potential benefits, such that it is theoretically possible for the majority of the 'wish-list' to be granted, there are many barriers to actual success. These include the commercial aspects of the technology. Although it is clear that there are benefits it is not clear that these will go back to the investors. Many unwise investments have been made and at this time very few returns have been made. It is clear that in the future the targets chosen will be considered much more carefully. We therefore have to be clear from whence subsequent investments might come. In the case of inbred crops like wheat and barley, it is clear that the current returns on plant breeding cannot pay for any major investments into improved agronomic traits for farmers. In these crops, improvements would be expected to be related to ones where the value can be returned later in the chain. Monsanto are currently trying to introduce a licensing system to regain their investment in transgenic cotton and it will be interesting to see if it works. If it does not, the possibilities of traits that benefit the farmers being introduced into inbred crops by commercial companies are very poor in the long-term.

Many of the advances that one might like to see that relate to yield improvements or other complex traits are limited by knowledge currently available. There are many hypotheses to test and much work to be done that may not lead to any commercial gain. Such research has traditionally been the responsibility of the public sector. Whether this will continue to be the case is dependent on the investment that is made by the taxpayers. Worldwide, this investment is declining and particularly in plant breeding, which is still a very necessary art even for rDNA crops.

CONCLUSIONS

The new biotechnology is a very powerful one which challenges many people's beliefs and conceptions. It arouses apprehension in large sections of the population including the Prince of Wales. These concerns have to be met and accepted before the technology can be widely introduced. The results of trying to do this in groups like the Biotechnology and Biological Sciences Research Council's Consensus Conference have shown that it can be attempted and many useful conclusions arose from the conference. However, much more needs to be done and many more discussions have to be had with the general public before acceptance is likely. Current progress in the US and elsewhere suggests that the discussions can be much more fruitful where there are concrete examples available. For example, vegetarian cheese made using an enzyme produced by biotechnology is widely available in the UK.

Some of the other considerations that lie between the research bench and the market include determination of which targets will generate significant added value, whether sufficient value can be recovered by investment in research, the costs of development, registration and acceptance, and the time scale from investment to return. A simple summary of where the UK currently stands in the development, application and marketing of crop biotechnology products and processes may be expressed as follows:

Upside

- the technology works
- the knowledge explosion will happen
- there are real possibilities for commercial and social benefits
- our research community is in the premier league

Downside

- the US has won the race to commercialisation
- EU crop releases are delayed
- the EU will import but not produce the first crop products
- major UK crops are not hybrids
- commercial investment in research and development under question
- public research funding under threat
- a lack of belief that public investment is necessary to realise potential benefits

The next few years will be crucial in that they will show whether UK agriculture will embrace and benefit from the potentials of plant biotechnology.

REFERENCE

Doubleday, O P (1996) Expectations of the growers of arable and horticultural crops. In: Marshall B J & Miller, F A (Eds)*Biotechnologies in agriculture and food - coming to the market*. CAS Paper 34. Reading: Centre for Agricultural Strategy.

Discussion (Papers 1 and 2)

Dr Alan Long (Vegetarian Economy and Green Agriculture) felt that the term 'customer', used by Oliver Doubleday (rather than just 'consumer') is very appropriate in the context of the issues being discussed at this conference to ensure that the customers become biotechnology-friendly in the same way that they are becoming computer-friendly. He stressed that there is a great responsibility on the schools and in the education of domestic science and home economics.

Professor Ben Miflin accepted this conclusion and added that whilst BBSRC, for example, assisted the process through sponsorship of the Consensus Conference, a great deal more needs to be done to make people more familiar with the technology, a subject he expected to be more fully debated later in the conference.

Ms Annabel Holt (Annabel's Crusade for the Environment) expressed concern about the risks for both wild herbs that are so beneficial to humans, and the environment, through the use of herbicides; she also questioned the effects of carcinogens in surfactants such as Roundup.

Professor Ben Miflin said in response that he does not think herbicide-tolerant crops will affect the acreage that is subjected to herbicides and that he recognises the problem of ensuring that herbicides only go on the weeds that we want to kill. He did not think biotechnology changes that situation and felt that it could actually improve it by making available better herbicides in those senses than in others. He also referred to the large amount of MAFF- and company-sponsored research being undertaken in his Institute, into how we can use our hedgerows and field margins in a much better way; and demonstrations at The Royal Agricultural Show and at other institutions showing how some of the plants about which concern has been expressed can be incorporated safely in the sense of not impinging on yield, into areas of the farm that are not used for production.

Dr Oliver Doubleday commented that so far as the wider environment is concerned, there is increasing awareness of how that impinges directly on farming activities, for example, he positively welcomes *Tifladromas* as being a control agent, and *Anthrocoris* which controls problems in pears. He stressed that he cares what happens in his hedgerows because some tree species harbour *Anthrocoris*, whilst others harbour pests, so he is becoming much more sophisticated in how he views the orchard environment and all that is happening in relation to broader agricultural crops.