THE ROYAL SOCIETY

April 1999
Ref: 6/99

Non-Food Crops

Response to the House of Lords Select Committee Inquiry on Non-Food Crops

Introduction

The Royal Society welcomes the opportunity to give its views on Non-Food Crops. The Society believes that non-food (industrial) crops are of great importance: it will continue to be active in providing advice to Government and others on this subject.

The Society would like to draw attention to the following publications which are of relevance to this inquiry: *Genetically Modified Plants for Food Use* (Royal Society Statement 1/98) and *The Regulation of Biotechnology in the UK* (Royal Society Statement 3/99).

This response has been endorsed by the Council of the Society. It was prepared by a group chaired by Professor P Bateson (Biological Secretary and Vice President of the Royal Society), and comprising Professor M Gale, Professor C Leaver, Dr G Lomonossoff, Dr J Ma, Mr J Macleod, Professor A Slabas, Professor A Smith and Dr S Lipworth (Secretary).

The main points made by the Society in this response are as follows:

- Non-food crops have significant potential to make an impact both on land use and economic activity, particularly those intended for use in energy production or as sources for fibres in biocomposites.

- Non-food crops used for the production of speciality chemicals, notably pharmaceuticals, are also likely to become increasingly economically viable, although this will depend on quality and the development of new processing techniques.

- The use of genetic modification techniques increases the number of potential applications for non-food crops. However, it is important to address potential environmental concerns during the development of such crops (see Statement on *GM plants for food use*).

- Few incentives, either from taxation or subsidies, promote long-term development of potentially important non-food crops. We recommend increased co-ordination and availability of research funding in order to take advantage of a rapidly developing area.

1. What is the potential for the development of non-food crops in the UK? Which crops, if any, are likely to prove significant in terms of economic activity or land use?

The potential for non-food crops in the UK is significant. However, the further development of non-food crops will depend on the demand for new products and processes derived from them. This demand is difficult to predict because a full understanding of the actual and potential applications, benefits and drawbacks of materials derived from non-food crops over traditional crops is still uncertain.

A useful approach to understanding the potential of non-food crops is to consider their potential end uses. These include:

- renewable energy crops e.g. biomass grown for conversion to energy (e.g. willow) and biofuel (biodiesel and bioethanol) which can replace fossil fuels and mineral oils;
- bulk chemicals, mainly oils, derived from linseed, oilseed rape and sunflowers;
- speciality chemicals such as pharmaceuticals, cosmetics and dyes; and
- speciality biocomposites such as biologically derived fibres (mainly derived from hemp and flax); lignocellulosic glues, dispersants, fertilisers, and additives; bioplastics, paper and board such as those derived from starches.

At present the most important non-food crops in the UK are linseed and oilseed rape.

Energy crops

While a large variety of crops might be used in any of the product groups listed above, the most significant non-food crops in terms of economic activity or land use are likely to be biomass non-food crops used in energy production. These include willow, poplar, and hemp.

Biocomposites

The interest in fibre crops and production, most notably flax, for use in construction composites (e.g. fibreglass alternatives) is substantial and increasing.

Almost all of the starch used by UK industry is imported, in the form of maize grain and starch (60% of UK industrial starch use is maize starch) and potato starch (30% of UK industrial starch use). Most or all of our requirements (approximately 200,000 tonnes p.a.) could be grown in the UK as wheat and potato with possible contributions from barley, oats, rye and quinoa. Starch is an essential component of paper, cardboard and related products, and is used widely in the manufacture of glues, pastes, paints, cosmetics, detergents, pharmaceuticals, and biodegradable plastics, and as an anti-sticking agent in, for example, plastic gloves and various sorts of moulds.

Speciality chemicals

The production of speciality chemicals from non-food crops is not expected to prove significant in terms of land-use however this too could change, for example if the potential for the use in the UK of plants as bioreactors is developed.

Genetically modified (GM) crops have potential for development in the UK. Recently, the emphasis has been on GM foods, but it is likely that more favourable public acceptance may develop of GM technology may develop from GM modifications that lead to new pharmaceuticals and other medical products, as well as raw materials for energy and plastics. The cost of production of pharmaceuticals in plants is likely to be far less that the cost of producing equivalent materials using fermenter (traditional manufacturing) technology. Given the huge biomass that can be produced from plants, it is quite possible that using plants in this way could result in the practical development of novel pharmaceuticals (e.g. vaccines) which are too expensive to produce conventionally.

In both the EU and US the interest in this type of technology is great. In 1998, the first two human clinical trials with vaccines derived from GM plants were reported in the scientific literature [1]. At present, all the research is done on a small scale under containment conditions. In the United States, plant biotechnology companies have already acquired farms to develop into pharmaceutical production facilities, working under controlled conditions as laid out by the US Food and Drug Administration.

Although the land requirement for GM crops may be relatively small for the production of high value pharmaceuticals, as the technology develops more ambitious projects may be undertaken to produce low cost medical products in bulk (for example, blood replacement products). In the area of GM protein production, agrobiotechnology can also be applied to non-medical areas such as industrial enzymes and these types of applications could involve significant demands on land.

Despite many potentially useful developments in non-food crops, in particular GM crops, concerns about wider ecological impacts and potential transfer of genes are considerable, as discussed in our statement *GM plants for food use*. It is important to address such concerns during the development of any non-food crop intended for future commercial use.

2. What is their potential to replace other less renewable resources, and to pay their way, in the long term? Can this be enhanced, e.g. by genetic modification of plants or plant viruses, or by advances in processing technologies? Can problems of consistency and reliability be overcome?

a) *Replacement potential and economic viability*

Fossil fuels and petrochemicals

The use of alternative raw materials in order to supplement or eventually replace less renewable resources is essential in the longer term in order to replace dwindling supplies of materials such as fossil fuels. Non-food plants may provide an alternative source of such raw materials with generally lower environmental impacts than those associated with fossil fuels. At present these materials are not nearly as widely used as they could be, because their costs are relatively high, and because their quality in some cases is relatively poor. The potential of energy crops to replace less renewable resources such as fossil fuels and petrochemicals with those derived from renewable plant based materials is complicated by socio-economic issues, for example the trade-offs between sustainable environmental benefits and short-term economic factors such as what people are prepared to pay. It is likely that socio-economic considerations will play an important role in determining the demand for renewable resources such as biodiesel. These issues make it difficult to base decisions on current cost comparisons alone.

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[1] 1998 Ma, J.K-C., B.Y.Hikmat, K. Wycoff, N.D. Vine, D. Chargelegue, L. Yu, M.B.Hein and T. Lehner. Characterization of a recombinant plant monoclonal secretory antibody and preventive immunotherapy in humans. Nature Medicine.4:601-607

The potential is, however, high for the development of new biomass crops and central to much of this will be developments in the genetic modification of plants. The potential for these crops to replace other, less renewable resources, will also depend on the presence of the proper infrastructure and mechanisms such as facilities that convert biomass to electrical power e.g. wood-fired power stations. It may also be possible to realise considerable short-term returns on investment in biomass crops such as poplar, willow and hemp.

Starch and oil from plants may replace many current uses of petrochemicals. Starch has great potential to replace petrochemical feedstocks (raw materials) in some aspects of the plastics and paint industries. Its advantage over petrochemicals is that it is a renewable and vastly abundant resource. Furthermore, its use does not make a net contribution to atmospheric CO_2, and products made from it are biodegradable. Several research groups and industries are trying to produce starch-based plastics with desirable combinations of resistance to moisture and biodegradability for a wide variety of applications. It is possible to buy, for example, microwave dishes, golf tees, ground-stabilising nets, pen casings and packaging granules made of starch rather than petrochemicals, and the list is increasing all the time. However, plastics manufacture accounts for only about 3% of the industrial use of starch in the UK.

Glucose or small oligosaccharides derived from starch are also being used increasingly as chemical feedstocks (raw materials) for the manufacture of detergents and components of paint, in place of feedstocks derived from petrochemicals. Starch is certainly not able to compete with petrochemicals for the plastics, surfactant and paint industries on purely economic terms at present. However, increases in the price of oil, the finite supply of this commodity, improvements in starch-based products and increasing consumer demand for "green" products would all favour starch over petrochemicals in future.

Speciality chemicals

Longer term returns will potentially be realised with ‘speciality’ crops, such as those involved in the production of pharmaceuticals. The use of plants to produce pharmaceuticals is definitely seen as a way of replacing existing fermenters that are very expensive to develop and run. Novel processing technologies are likely to be necessary if the products are to be extracted and purified from the plants. However, in certain instances purification may not be necessary, for example in the development of "edible vaccines". The limiting factor in this case will be the development of crops that produce high quantities of the desired speciality product and development of means by which to rapidly and inexpensively extract the desired product.

b) Contribution of genetic modification and technological improvements.

There is no doubt that the application of genetic modification can dramatically enhance the utility of non-food crops. Genetic modification has numerous potential applications in the improvement of crops for non-food uses. It has contributed, for example, to:

- the production of new oils with valuable industrial properties by the introduction of single genes from wild species of plant into oilseed rape, reducing the use of petrochemically-derived oils;
- the modification of the structure of wood, to reduce the need for chemical treatment during pulping and thus reduce the enormous effluent problems of the paper industry; and

- the production in plants of antibodies or of components of viruses for use in vaccines, which can reduce the expense and increase the availability of treatment for serious diseases, and reduce the use of animals in medicine.

Other examples of the potential benefits of genetic modification can be found in starch crops where it can reduce the dependence on post-extraction modification procedures. Different end users require starches with different physical properties. To meet this demand, starch from maize or potato is modified by chemical, enzymic or physical methods to produce a whole range of different functionalities. These modifications are expensive and energy-consuming, and they generate polluting wastes. The production of GM cultivars of starch crops, each with a different complement of starch synthesising enzymes and hence producing starches with naturally different functionalities, should reduce the need for post-extraction modification. Genetic modification of starch synthesis may also result in plants which produce starches with novel functionalities – not thus far obtained through post-extraction processes. Such material may expand the industrial use of starch as a replacement for petrochemicals.

It is important to appreciate that there are plant species not currently grown as UK crops that naturally produce starches with functionalities quite different from those of maize and potato starch. The extent to which use of starch from such species, rather than genetic modification of existing starch crops, could reduce the need for post extraction modification and offer novel functionalities has not been fully explored. This would be a long-term goal as most of the species have poor agronomic potential in the UK. Genetic modification of starch synthesis is well advanced, and a transgenic potato cultivar containing a starch for industrial use has reached the final stages of the regulatory procedures required before commercial release in Europe.

GM plants producing pharmaceuticals show great potential. One example of plant product nearest to commercial realisation is a vaccine against tooth decay, and GM plants represent the only means available for production of this complicated vaccine. For other pharmaceuticals, non-food plants can offer a cheaper means of production compared with methods currently available. The most obvious reason for this is the potential agricultural scale on which drugs and vaccines could be produced and the financial benefits that will result. However there are other significant technical advantages that will benefit the pharmaceutical industry. One advantage is that there is a broad similarity between the biochemistry of plant and mammalian cells. This allows the production of molecules, some of which could be made without the use of costly mammalian cell cultures, or even experimental animals. A second advantage is that plants do not host any human pathogens such as viruses or prions, which makes their use for pharmaceutical production attractive on the grounds of safety.

Enhancement of processing technologies is an important development stage and indeed research in this area has been strongly supported by the EU. A considerable research effort has been directed into improvements through genetic modification. These have been successful in areas such as improving disease resistance, enhancing fibre content and biomass for energy production as well as in modifying enzymatic pathways and developing new metabolic pathways in crops which can lead to products such as biodegradable plastics, new starches, new oils.

This inquiry specifically excludes the traditional uses of tobacco, however, its usefulness in the field of genetic modification needs to be mentioned. Certain varieties of tobacco are currently the plant species of choice for genetic transformation for the production of recombinant proteins for pharmaceutical purposes. Tobacco has been studied for many years as a model plant, and much of the basic plant science has been carried out in this species. Tobacco is extremely easy to genetically modify, regenerate and grow. Although it is unlikely that tobacco will be grown in the field in the UK, its use under cover or in green houses is certainly an important option for producing high value medicines that are not subject to large demand. The overall characteristics of tobacco make it an important candidate in this area of protein production.

Although genetic modification has the potential to increase the scope of developments in non-food crops it is important that current environmental concerns are addressed by further research. Possible environmental impacts of GM crops were discussed at length in *GM crops for food use*. However, it is likely that the most significant concern for GM non-food crops will be the likelihood of gene transfer to other plants, in particular to food crops. If such transfer is likely to be detrimental then statutory isolation measures may be required.

c) Consistency and reliability

Energy crops vs. petrochemicals

Consistency and reliability are important factors when considering the potential of non-food crop products to replace less renewable resources. A more uniform and higher value crop could be achieved by traditional methods, as is currently the practice with biomass crops that are coppiced. Genetic modification could be used to enhance the desirable attributes of such crops.

While fossil fuel oil is available, industry may prefer tried and tested chemical processes to a novel process based on plant-derived materials. Firstly, plant-derived materials are often less homogeneous and less consistent between batches than oil derived from fossil fuels. More research is needed on the initial processing of plant material to yield "clean" products - for example the use of wheat starch would be boosted by better processes to separate it from protein during milling. Secondly, the manufacture of a product from plant polymers may require completely different conditions and equipment from those needed for oil-based processes: investment in research and equipment will be needed. Thirdly, if the most suitable plant product to replace a petrochemical product is from a specialised crop or a specific cultivar and is needed in relatively small amounts, manufacturers may feel that the supply could be unreliable. Innovative forward thinking and investment is required by industry if plant products are to be developed.

Speciality chemicals

Companies involved in the processing of speciality chemicals are likely to be multinational and therefore may not be solely reliant on single crops grown in the UK. For high value pharmaceuticals, the problem may be overcome by growing the crops under controlled (i.e. greenhouse) conditions.

With regard to starch based products there are two main concerns. Firstly, starch-based plastics are thus far of poorer quality than those made from petrochemicals. This may not be a problem for some products, and the consumer may well accept an environmentally friendly product of slightly inferior quality. Consumer education may be as important as further research in promoting the widespread use of starch plastics. Second, where starch is one of several components of a product, end-users are understandably reluctant to become dependent upon what may be a relatively small crop of a GM line "designed" to produce starch of the correct functionality, in preference to a standard starch which has been modified after extraction to give the correct functionality. Modification after extraction gives a completely reliable source of material, whereas a crop failure of the "designed" cultivar could jeopardise an industrial process. There is however no reason to suppose that the stability of starch characters and the agronomic performance of GM starch crops will be poorer than those of conventional cultivars.

3. What are the environmental and ecological implications of the development of non-food crops? How far can Life Cycle Analysis of non-food crops be carried out, for comparison with conventional materials?

There are positive and negative aspects associated with the development of non-food crops. These will have to be evaluated on a case by case basis and generalisations should not be made. Non-food crops need to be evaluated by comparison with alternative methods of production. This can be done by Life Cycle Assessments. Life Cycle Assessment involves making comparisons of the environmental impacts at each stage of the production processes including the use of the products and their ultimate fate. This approach, is however, problematic due to the paucity of information upon which to base decisions and the inherent differences, nature and scope of plant based (agricultural) production compared with more conventional industrial processes.

Depending on the type of non-food crop, the environmental implications can be quite limited. For "native" non-food crops like poplar, willow and flax the impact is likely to be limited. In fact, it is conceivable that the impact of these crops might be less than that of food crops raised on the same land. Furthermore, non-food crops products can benefit the environment by requiring less herbicide inputs. Certain plant species, such as *Miscanthus* (elephant grass) have the ability to extract metals from soils and can be used in the bioremediation of degraded environments. However, more information is needed as there may be some problems associated with biomass crops in that they may extract more water from the soil than traditional agricultural crops. Although there may be potential negative environmental and ecological implications associated with non-food crops these need to be contrasted and compared with those that are produced when making any changes to crops and farming practices.

Environmental assessments of impact are further complicated when considering the implications of GM plants compared with other naturally evolved systems. A particular concern of non-food industrial crops is the likelihood of crossing with wild relatives (Royal Society statement 1/99). Potential effects of non-food crops on the ecosystem should also be considered for both GM and non-GM plants. The use of GM non-food crops to produce foreign proteins (such as antibodies) poses particular concerns with regard to possible gene exchange with wild relatives and other crops. It will be essential to minimise such gene transfer by isolation or by GM to prevent pollen production for example (Royal Society statement 1/99).

It is notable that in general, the recombinant proteins are produced in all parts of the plant. Therefore the plants can be harvested before maturation of any of the sexual organs which eliminates the risks associated with contamination of the environment by pollen or pollinating insects. It is also possible to use inducible promoters that allow production of the recombinant protein to be "switched on". This is a critical development which means that it maybe possible to develop a pharmaceutical product that is not produced in the plant in the field, but only expressed post-harvest, once the biomass has been collected and stored.

GM non-food crops that are used in biomass production are likely to be relatively acceptable to the public since the modification is unlikely to have a detrimental impact on the environment, for example, GM resulting in enhanced energy content in trees for biomass production. Furthermore, the likelihood of "escape" of genes from GM plants (so-called "genetic pollution") is very low as the plant material is generally harvested before sexual reproduction takes place.

Assessments will need to be performed both on GM and non-GM material if we are to be fully aware of their environmental impacts. Assessments will need to be made of the relative impacts of harvesting and downstream processing of both GM and non-GM products. Such costs could include transport, pollution by emissions and by-product disposal.

4. Are there regulatory barriers to the development of non-food crops, or disincentives in the current system of taxation and subsidies?

There is uncertainty surrounding the time required for approval of new crops in current European legislation, particularly when such crops are GM. This makes investment by industry very difficult to justify. The RS has urged the Government to press for short time-tabling and greater transparency following the revision of the legislation (Royal Society statement 3/99).

The use of plants to produce pharmaceutical products, such as vaccines, is a novel approach and the current regulatory regime may need adjustment to specifically deal with such products. Pharmaceuticals produced in plants would also have to be shown to as safe and efficacious as the equivalent product produced by more conventional means.

In starch production there are very strong regulatory barriers. There are EU support payments on a quota basis to potato starch manufacturers. The UK does not have any of this quota, preventing the further development of a UK potato starch industry. Even if support were available, the growth of potatoes for starch would require a large shift in UK agricultural practice. The success of the Dutch potato starch industry comes from large-scale, intensive potato growing to supply large local processing plants. It would be possible to produce much of the UK starch requirement from home-grown wheat[2]. However the viability of a starch industry based on home-grown wheat would depend on the level of duty on cereal imports.

There are currently few incentives, either from taxation or subsidies, to promote the long term development of these crops. Although there have been several efforts to promote academic and strategic research into non-food crops through public funding in recent years, overall, though, funding has been rather piecemeal. At present there is a significant focus by the major research funding bodies on food crops. In as much as this makes research on non-food crops difficult, this is a disincentive in the development of these crops. We recommend increased funding for the development of non-food crops, from the relevant

[2] 1996 report Industrial Markets for UK Grown Plant Polysaccharides LINK programme on Crops for Industrial Use

bodies such as MAFF and the Forestry Commission which should be made available to competitive tender.

5. In the light of the above,

(a) are the current UK and EU subsidies for non-food crops, and the proposals under Agenda 2000, appropriate;

In sharp contrast to the UK, the EC has identified the production of non-food crops, such as biomass crops for energy, as a key target area for funding under the Framework V research funding programme. Accelerated uptake of non-food crops developed under this research programme would be achieved by appropriate subsidies. In certain countries in Europe these are available and biodiesel is a case in point. At present in the UK there is insufficient funding to promote development.

What are required are targets which can be concentrated on without changing the crop every few years. In this respect uncertainties of the Common Agricultural Policy (CAP) reform are not helping. CAP reforms introduced in 1992 were aimed at reducing food production across the EU by taking a percentage of agricultural land out of food farming. The so-called set-aside land attracted subsides for the growing of non-food crops. Proposed CAP reforms, currently under review in the light of EU expansion, are set out in the EC 1997 document *Agenda 2000*. If implemented these reforms could result in a decline in the production of non-food crops due to a reduction in subsidies.

(b) are the local, national and EU regulatory regimes appropriate; and

The UK, regulatory regime is appropriate, but also under review. However, regulatory regimes are not uniform across the EU and this is not helping to promote non-food crops.

(c) is the level and direction of UK and EU public funding for research and development appropriate?

As indicated above, the direction and amount of funding for research in the UK is inadequate. This is in sharp contrast to the EU where the direction is focused, and the funding, appears at present to be significant. In the next round of Framework V, non-food crops has been highlighted for funding and will attract a high number of quality applications.

In the UK public funding for research into GM crops for medicinal purposes has been less well managed. This is partly due to the long-standing distinction between research proposals submitted to different funding bodies and the traditional emphasis of these funding sources. Effort needs to be directed at a few selected targets with longer time scales appropriate to this research. This can only occur if longer-term funding (more than three years) of the programmes is achieved. It needs to be recognised more clearly that this area of research is truly multi-disciplinary and requires expertise both from plant scientists as well as human and animal scientists. The interaction between appropriate parties needs to be maintained and in some instances initiated.

Although there is consumer interest in ‘environmentally friendly’ products, this does not appear to be a more important consideration for most consumers at present than high quality and low cost. The cost of plant materials to industry is strongly related to agricultural and trade policy rather than the actual cost of production. The present quality of plant-based products is in part a reflection of the lack of research on such materials. This can be addressed by further research that will generate new and exciting ideas for the development and improvement of non-food crops. However, this will require financial incentives, longer term research funding, a level European regulatory framework and national strategy on the development of non-food crops.