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The Precautionary Principle and GMOs: taking a scientific approach to risk

Genetically modified organisms (GMOs) are produced by transferring genes from one organism (usually an unrelated species) into another. The GMO may, for example, be a crop for food use, an animal to provide meat or a microorganism to degrade toxic waste. In these cases, the GE organism may be released into the environment where it can grow and multiply. Its foreign genes may transfer into related wild species or the GMO may behave unpredictably, become out of control and damage ecosystems. Any effects are likely to be irreversible. Our knowledge of how and when harm may arise is limited and surprises are likely.

When faced with such situations, how should decisions be made about whether and, if so, how to produce and use a GMO? One obvious approach is to apply the Precautionary Principle. This principle has been developed as a result of experiences with chemical and other forms of pollution with the intention of avoiding such harm arising in the future. The Precautionary Principle is intended to be a general rule in situations where there is the potential for serious or irreversible threats to health and the environment and requires action to be taken to avoid such threats even where definite proof of harm does not yet exist. It stops the lack of scientific certainty being used to delay preventive action[1,2,3]. From asbestos, PCBs and ozone depletion to mad cow disease, conventional risk assessments have failed and the lessons of waiting too long for proof of harm before taking action have shown that a rigorous precautionary approach is long overdue[4].

However, the Precautionary Principle is sometimes criticised as being unscientific, and stifling progress. This briefing reviews why precaution is so vital in relation to GMOs, how it demands a more rigorous approach to science and brings more democracy into decisions about whether or not to take risks and why it does not present a barrier to progress. Rather than a presumption that benefits for industry should take precedent, under a precautionary approach a voice is given to the environment, individuals and communities who stand to be affected if things go wrong.

GMOs: their potential to cause significant, irreversible harm

When organisms are genetically engineered, a package of genes is introduced which includes genes to switch on another ‘gene of interest’ (that makes a crop produce an insecticide or be tolerant to chemical weedkillers, for example) together with a gene to switch it off. A marker gene is also included because the GE process is very inefficient and only a small proportion of cells incorporate the foreign DNA. So a gene that gives an identifiable change, such as antibiotic resistance or florescence, is also included. All these genes may come from any species and bacterial and viral genes are commonly used.

The supporters of genetic engineering claim that the process is more precise than conventional breeding because it is known exactly what genes are added and, therefore, that their effects can be predicted. However, the GE process is not controllable and new scientific research shows that gene function is much more complex than previously thought:

- **the position at which genes are inserted is random** – other genes may be disrupted and their function altered;
- **many copies may be integrated, additional fragments inserted, gene sequences rearranged and deleted**[5,6,7] – which may result in lack of operation of the genes, instability or interference with other gene function;
- **one gene does not code for only one function** – findings from studies such as the human genome project have shown that there are far fewer genes in higher organisms than was predicted – 30-40,000 in man rather than the 120-140,000 originally thought[8]. This means that genes or parts of genes may be involved in different functions, depending on how they are read and which other genes are involved. This undermines the assumption that adding a gene with one known function means that this is the only way it will behave in practice[9]. Indeed, the detailed functioning of DNA is not well understood. Scientific theories and understanding of the ways in which genes work is constantly developing, giving new insights on the complexity of gene function[10];
- **a package of genes is introduced for which there is no evolutionary precedent** – the introduced genes come from a mix of species which have never packaged together before. In a complex genome, how they will behave and interact over time is unknown.

The consequence of such complexity is that unpredictable effects are likely. Once released in the environment, it will not be possible to recall a living organism so any impacts are likely to be irreversible because organisms are self replicating. If the GMOs cross with related wild species, the genetic change may be incorporated in the natural gene pool and alter the path of evolution.

The kinds of impacts that may occur include:

- GE crops becoming more invasive, weedy and difficult to manage;
- wild plants acquiring the genes and so changing their characteristics and altering ecosystems. For example, if wild plants gain a gene to produce a protein toxic to a range of insects or other organisms, they may survive better than other plants;
- new toxins or allergens being produced as a result of interference with natural gene function or unexpected interactions between gene products;

There is evidence that things regularly DO go wrong with GMOs:

- Experiments to make potatoes resistant to insects using a lectin gene led to lowered levels of the plant's natural insect deterrent chemicals, glycoalkaloids. This was shown to be an unintended effect of the GE process itself, as the introduction of a different insect resistance gene had the same effect[11].

- Yeast which had been genetically engineered to improve alcohol fermentation unexpectedly had up to 30 times the concentration of methylglyoxal (a highly toxic compound) compared to the control non-GE strain[12].

- Researchers at Monsanto who were trying to increase the content of carotenoids (chemicals which are used to form vitamin A) in oilseed rape (canola) found that vitamin E and chlorophyll levels in the seeds were dramatically and inexplicably reduced[13].

- Other researchers trying to genetically engineer a carotenoid pathway in tomatoes found over-expression of a gene caused unexpected dwarfism in the plant[14].

- Monsanto's GE Roundup Ready soybeans have suffered unexpected crop losses in hot, dry weather due to stem splitting caused, most probably, by increased lignin[15]. The soybeans' phytoestrogen levels are also 12-14 % less than in conventional soybeans, which may mean that soy-based products derived from Roundup Ready soybeans would be less useful as sources of phytoestrogens which are thought to be beneficial in adult diets[16].

No independent monitoring takes place of the GE crops grown across the world so there will be no early warnings of unexpected effects.

It is also becoming clear how unmanageable the risks of GE crops are. In Canada, volunteer oilseed rape weeds that are tolerant to three herbicides (Liberty, Roundup and Clearfield) were first identified in 1998, only 3 years after GE herbicide tolerant oilseed rape was first grown[17,18]. The problem has arisen because some seed is shed at harvest time, remains in the ground and germinates in future years. When the plants emerge in subsequent crops of a different species they are then unwanted weeds ('volunteers') which have to be removed by the farmer. This resistance to more than one herbicide is known as 'gene stacking' and arises through pollination of one herbicide tolerant variety by another. The emergence of super-weeds in Canada is driving up the use of other, more toxic chemicals. Both 2,4-D and paraquat (grammoxone) are being recommended by government agencies to control herbicide tolerant oilseed rape volunteers in Canada[19].

The unpredictable changes GE can cause, the difficulties there will be dealing with any problems and the potential for GMOs to multiply and grow mean that GMOs fall firmly within the scope of the precautionary principle. Conventional risk assessments, biased towards the interests of the biotechnology industry (see Box 1), are very unlikely to provide the degree of protection required.

How risk assessment fails the environment and human health

In a risk assessment of releasing a GMO to the environment, risk may be described by a seemingly simple equation:

Hazard x probability = risk

The hazard is the type of harm that might arise, a cancer or death of an animal, for example. The probability is how likely this is to happen, ranging from very low - such as one in a million, to high - such as one in ten. Probability, like hazard, is a complex issue covering a range of factors. For example, with gene flow from one plant species to another this includes how closely related the two species are, whether they flower at the same time, how far apart they grow, whether they are pollinated by insects or the wind and the prevailing weather. This is sometimes called 'exposure' in chemical risk assessment.

Risk assessment is often portrayed as a relatively straight forward process – simply identify all possible hazards, calculate the probability that they may arise, work out what the risk is, decide if it is acceptable and how to manage it. It sounds very scientific and impartial, but it's not. Initially conceived to deal with failures in machinery, it struggles with the complexity of the natural environment. Because it is this system that underlies the regulation of GMOs worldwide, protection of the environment and human health is being compromised.

There is now a well established critique of conventional risk assessment which has shown that the process is subject to scientific, social, political and economic judgements which tend not to be explicit[20]. These judgements are seen in:

- **which hazards are considered** – someone has to choose what to include and exclude. In the case of GMOs, the risk assessment focuses on the genetic change and generally excludes indirect effects and secondary impacts on organisms in the food web or implications for non-GE and organic farmers. It is this framing of the risk assessment that drives the outcome and reflects the interests of those designing the assessment;
- **calculating their probability** – there is always scientific uncertainty, and a choice has to be made. With GMOs it is unlikely that probability of an event happening can ever be calculated with any confidence as it covers a host of different environmental and ecological factors. It also depends on whether people follow the rules, which is often not the case;
- **what is an acceptable risk** – whether a potential impact is significant or not is a matter of social or even personal judgement – it depends on social, economic and cultural factors. Risk assessment conceals this and presents risk as something to be quantitatively measured by scientists and managed by experts to "acceptable" levels. The issue of genetic contamination of indigenous

maize varieties in Mexico will be viewed very differently by Mexicans, who bear the risk, and Americans whose corporations profit from GE maize;
- **dealing with ignorance and surprises** – when evidence is patchy or missing, deciding whether there may be a problem or not depends on informed prediction, using available information and drawing on lessons of the past in order to come to a reasoned but cautious decision. Risk assessment underestimates this problem, assuming that knowledge and understanding are sufficient to calculate risk, or will become sufficient in time if further research is commissioned.

The process is also constrained because only hazards that can be measured are commonly included in risk assessments. Long-term subtle changes in behaviour or fertility are not easily included. What might ultimately prove to be the most important changes may simply not be part of the assessment.

Underlying the risk assessment of GE crops is an assumption that they form a positive development for agriculture[21]. Although rarely acknowledged in risk assessment, this bias shapes the way in which GMOs are evaluated. The odds are stacked in favour of the industry and against the environment and human health.

What does the Precautionary Principle mean in practice?

The Precautionary Principle was first used formally in German law in the mid-1970s. Since then it has been adopted as an approach to protection of environmental and human health in many other national, regional and international laws. The Cartagena Protocol on transboundary movements of GMOs is based on the Precautionary Principle and the principle has been endorsed by the European Commission. But what does it mean in practice? Too often, precaution translates into a conventional risk assessment as it has under the European Deliberate Release Directives[22] which leaves the pro-biotech bias in place (see Box 1).

The 'Precautionary Principle' builds on a series of straightforward and well-established ideas that[23,24]:

- '*prevention is better than cure*';
- '*the polluter should pay*';
- we should look for '*no regrets*' options;
- we should recognise the intrinsic value of non-human – as well as human – life.
- the *complexity* and *variability* of the real world limits the ability of scientific knowledge to predict;
- we must recognise the *vulnerability* of the natural environment;
- the *rights* of those who stand to be affected by an activity, must be prioritised rather than those who stand to benefit from it;
- there must be scrutiny of all available *alternatives* and an examination of *justifications* and *benefits* as well as risks and costs.
- *long-term, holistic and inclusive* perspectives are needed in environmental protection.

New techniques are being developed which allow these ideas to work in practice. Deliberative techniques, multi-criteria evaluation and other approaches provide new ways of conducting technology evaluation and must be brought into GMO assessments. Importantly, because a precautionary approach takes a much broader scope, it explicitly considers uncertainty and ignorance and evaluates alternatives. Policy analysts have concluded that the Precautionary Principle is more scientific than conventional risk assessment[25,23].

Precaution and GMOs: bringing science to the fore

Genetic engineering can change organisms in far reaching and unpredictable ways. Assessing their impacts and whether they are acceptable must take into account the complexity of ecosystems, scientific ignorance (the "unknown unknowns") and uncertainty. Conventional risk assessment denies the potential for surprises and narrows the scope of harm to be evaluated to a limited range of factors. It is often undertaken by a restricted group of specialists whose narrow expertise acts against a comprehensive approach. Whilst science is used in the assessment, the exclusion of wider criteria such as indirect impacts on agriculture and biodiversity and lack of attention to uncertainty is not scientifically justifiable.

A precautionary approach (see Box 2) does not stifle progress but can encourage innovation more widely by stimulating the search for alternatives and valuing diversity. In contrast, the demand for proof of harm before action is taken can lead to 'paralysis by analysis'[4], as old practices are defended to the bitter end.

Therefore, a precautionary approach introduces a more scientifically rigorous analysis, with a broader scope and wider range of experts. Precaution is involved at all steps in decision making in areas where action may lead to seriously harmful effects, from the practice of science and the research agenda, to regulation and governance. Because the threats of GE are so broad, and harmful impacts could be severe and irreversible, the precautionary principle must be strictly applied.

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[1] Raffensberger, C. and J. Tickner (1999), *Protecting Public Health and the Environment: implementing the Precautionary Principle*. Washington: Island Press.

[2] Fisher,E. and R. Harding (1999) *Perspectives on the Precautionary Principle*, Sydney: Federation Press.

[3] O'Riordan,T and J. Cameron (1994) *Interpreting the Precautionary Principle*, London: Earthscan.

[4] Harremoës, P., Gee, D., MacGarvin, M., Stirling, A., Keys, J., Wynne, B., and Guedes Vaz, S. (editors) 2002. *The Precautionary Principle in the 20th Century: late lessons from early warnings.* London: Earthscan.

[5] Labra, M., Savini, C., Bracale, M., Pelucchi, N., Colombo, L., Bardini, M. & Sala, F. (2001) Genomic changes in transgenic rice (*Oryza sativa* L.) plants produced by infecting calli with *Agrobacterium tumefaciens*. *Plant Cell Reports*, **20**, 325-330.

[6] Shunhong Dai, Ping Zheng, Philippe Marmey, Shiping Zhang, Wenzhong Tian, Shouyi Chen, Roger N. Beachy & Claude Fauquet (2001). Comparative analysis of transgenic rice plants obtained by *Agrobacterium*-mediated transformation and particle bombardment. *Molecular Breeding* **7**: 25–33.

[7] Windels, P., Taverniers, I., Depicker, A., Van Bockstaele, E. & De Loose, M. (2001) Characterisation of the Roundup Ready soybean insert. *European Food Research Technology*, **213**, 107-112.

[8] International Human Genome Sequencing Consortium (2001) Initial sequencing an analysis of the human genome. *Nature* 409: 860-921.

[9] Commoner, B. (2002) Unravelling the DNA myth. The spurious foundation of genetic engineering. *Harper's Magazine,* February. Available on www.mindfully.org/GE/GE4/DNA-Myth-CommonerFeb02.htm.

[10] e.g. Dennis, C. (2002) The brave new world of RNA. Nature, 418, pg. 1222-124 and related articles in Nature Insight –RNA, 11th July 2002.

[11] Birch, A.N.E., GMOghegan, I.E., Griffiths, D.W. & McNicol, J.W. (2002) The effect of genetic transformations for pest resistance on foliar solanidine-based glycoalkaloids of potato (*Solanum tuberosum*) *Ann. Appl. Biol* 140:143-149.

[12] Inose, T. & Murata, K. (1995) Enhanced accumulation of toxic compound in yeast cells having high glycolytic activity: a case study on the safety of genetically engineered yeast. *International Journal of Food Science and Technology*, **30**, 141-146.

[13] Shewmaker, C.K., Sheehy, J.A., Daley, M., Colburn, S. & Yang Ke, D. (1999) Seed-specific overexpression of phytoene synthase: increase in cartenoids and other metabolic effects. *The Plant Journal*, **20**, 401-412.

[14] Fray, R.G., Wallace, A., Fraser, P.D., Valero. D., Hedden, P., Bramley, P.M. & Grierson, D. (1995) Constitutive expression of a fruit phytoene synthase gene in transgenic tomatoes causes dwarfism by redirecting metabolites from the gibberellin pathway. *The Plant Journal*, **8**, 693-701.

[15] Coghlan, A. (1999) Splitting headache – Monsanto's modified soybeans are cracking up in the heat. *New Scientist*, 20th November, p.25.

[16] Lappé, M.A., Bailey, E.B., Childress, C.C. & Setchell, K.D.R. (1998/1999) Alterations in Clinically Important Phytoestrogens in Genetically Modified, Herbicide-Tolerant Soybeans. *Journal of Medicinal Food*, **1**, 241-245.

[17] Downey, R.K. (1999) Gene flow and rape – the Canadian experience. 1999 BCPC Symposium Proceedings No. 72: Gene flow and agriculture: relevance for transgenic crops. British Crop Protection Council: Farnham.

[18] Hall, L., Topinka, K., Huffman, J., Davis, L. & Good, A. (2000) Pollen flow between herbicide-resistant *Brassica napus* is the cause of multiple-resistant *B. napus* volunteers. *Weed Science* 48: 688-694.

[19] Alberta Agriculture, Food and Rural Development (2002) Outcrossing Between Canola Varieties - A Volunteer Canola Control Issue. http://www.agric.gov.ab.ca/crops/canola/outcrossing.html

[20] Stirling, A (1998) Risk at a turning point? *Journal of Risk Research* 1: 97-110, 1998.

[21] Levidow, L. (1994) Biotechnology regulation as symbolic normalisation. *Technology Analysis and Strategic Management* 6(3) : pp 273-288.

[22] Mayer, S. & Stirling, A. (2002) Finding a precautionary approach to technological developments – lessons for the evaluation of GM crops. *Journal of Agricultural and Environmental Ethics* 15: 57-71.

[23] Stirling, A (1999) Science and precaution in the management of technological risk. Report for the European Commission – JRC Institute of Prospective Technological Studies, Seville. http://www.jrc.es/pub/EURdoc/eur19056Ien.pdf

[24] Stirling, A. (1999) Science and precaution in the management of technological risk. Volume II Case Studies. Report for the European Commission – JRC Institute of Prospective Technological Studies, Seville. http://www.jrc.es/pub/EURdoc/eur19056IIen.pdf

[25] European Commission (2000), *Communication on the Precautionary Principle*, COM(2000)1, Brussels: European Commission.