Risk, Hazard, Damage –
Specification of Criteria to Assess Environmental Impact of Genetically Modified Organisms

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Summary of the Conference by

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The aim of the Hannover conference was to compile criteria for the risk assessment of Genetically Modified Organisms (GMO). The programme allowed for presentation and discussion of concepts, methods, and case studies with inputs by speakers from Austria, Canada, England, France, Germany, Switzerland, and the US.

According to EU directive 2001/18 and EU regulation on novel food and feed, to avoid adverse effects of the release and placing on the market of GMOs an environmental impact assessment has to be carried out, based on the precautionary principle. General criteria for environmental risk, hazard, and damage are, however, lacking. There is also no agreement about the species and the kind of ecosystem that have to be protected although, in general, a decline of biodiversity is considered to be undesirable. The baseline to be used for comparison is not defined either. It has been stressed that the concepts of exposure and hazard have been developed with respect to chemicals, but GMOs are living organisms whose characters extend beyond those of chemicals because of their capability to multiply, mutate, recombine, persist, and actively interact and spread. Therefore, whatever the tolerance to risks from GMOs may be, it should be lower than that which is commonly accepted with respect to chemicals.

The notion “Adverse effects on the environment“ due to release of GMOs may be based on various theoretical concepts such as the theory of evolutionary integrity, the threshold theory, the theory of similarity between a GMO and its non-GM counterpart, the theory of selective advantages of GMOs, or the theory of impacts beyond natural fluctuation. Whether sheer presence of transgenes in organisms and ecosystems has to be considered as damage remains an open question.

The degree of damage caused by a given GMO will also depend on the recipient ecosystem, but it is not yet clear how to take into account sensitive ecosystems during the risk assessment process. According to Austrian studies, the effects of agricultural practice may be just as important as the effects of gene transfer and invasiveness. The methodology of “life cycle analysis“ may be helpful for comparison of impacts by GMOs with those of conventionally bred and organically grown crops. In a research project in Switzerland using questionnaires and developing scenarios, attempts are made to establish damage thresholds that are socially accepted. The approach of problem formulation and options assessment (PFOA) may help scientists involved in environmental risk assessment to create the context for societal dialogue about GM crop adoption. Following the PFOA approach, after identifying the problem as an unmet need that requires change, the importance of this problem relative to other problems is clarified. Afterwards, alternative solutions are discussed taking into account available data, limits of our understanding and uncertainty. This process has been applied to guide pre-release risk assessment in selected cases.

Decisions on deregulation of GMOs in the US seem to have occurred in part on flawed data. Data about environmental risk assessments provided by biotech companies to support their applications quite often did not fulfil the requirements of design and statistical rigor to detect real effects (the number of replicates was mostly too small and the duration of experiments was frequently too short). This was shown by analysis of application dossiers for Bt crops in the US. Moreover, most data were classified as confidential and have not been published in peer-reviewed journals.

The introduction of GMOs such as herbicide resistant (HR) crops can change radically the way crops are managed. From past experience it can be learned that intensive crop management has the most profound effect on the biodiversity of non-crops in farmed areas. The UK farm-scale evaluations (FSE) of HR transgenic crops have shown that in HR oilseed rape and beet, abundance and biodiversity of wild plants and of arthropods were much lower than in conventionally managed crops. Compared to conventional maize treated with the highly effective herbicide atrazine, in HR transgenic maize higher biomass of wild plants was found (however, because of its persistence and toxicity atrazine has been banned in the EU recently). These data indicate that biodiversity in arable land could be reduced and policies to conserve and enhance biodiversity might be counteracted by introduction of these crops.

Experience gained from widespread cultivation of GM crops in the US and Canada with regard to the consequences of hybridization and evolution of resistance in weeds shows that economic and environmental damage can result if crops contaminated by GM material cannot be marketed in certain countries and if more sustainable crop management methods cannot be applied any more.

Increased reliance on HR crops and the application of the respective broad-spectrum herbicides will inevitably lead to weed shift and the evolution of weed species resistant to these herbicides, as shown by the rapid spread of glyphosate resistant horseweed (C*onyza canadensis*) in soybean in more than nine US states within the last few years. To combat such hard-to-control weeds, dose and number of herbicides applied, including so called old and highly toxic herbicides (e.g. paraquat, 2,4-D), have increased. For this reason, after an initial decline in herbicide use with the introduction of HR crops, total herbicide use in the US has risen significantly.

Although commercialization of GM crops presumes containability in time and space, containability cannot be achieved due to the reproductive biology of plants. In addition, human error seems to play an important role in the failure to contain transgenes. Therefore, gene flow from transgenic crops will occur via pollen and seeds and lead to “same crop mixing“, as observed in numerous cases in the US and Canada resulting also in widespread GM contamination of seedlots of conventional crops. Even non-approved transgenes do occasionally show up in seedlots. The unintended large scale spread of GM oilseed rape in Canada and of GM maize in Mexico may serve as an additional example. Transgenes introduced into wheat are expected to spread in a similar fashion. The commercialization of GM wheat resistant to glyphosate would also threaten the economic sustainability of low-disturbance direct seeding which reduces soil erosion. In particular, if GM crops with novel pharmaceutical and industrial traits are involved, gene spread by pollen and seeds and accidental intermingling will pose specific risks for human and environmental health and for the farmers.

Introgression of GM traits into natural plant populations may also occur provided sexually compatible wild plants are present in the cultivation area of the respective GM crop. In a first step to assess possible ecological consequences of transgene movement, a quantitative approach may be applied. Studies on gene flow from oilseed rape (*Brassica napus*) to bargeman’s cabbage (*Brassica rapa*) growing close to oilseed rape fields or along waterways indicated that about 32,000 hybrids per year might be expected in the UK.

Gene flow via horizontal gene transfer from plants to microorganisms cannot be ruled out, although it may be a rare event. If transgenes exhibit (partial) homology to bacterial sequences, transformation of microorganisms with transgenic DNA may be facilitated by (illegitimate) recombination.

In summary, the excellent presentations allowed to gain an overview about various environmental impacts potentially exerted by the release of GMOs, some of these undesirable impacts have shown up already in countries with extensive cultivation of GM crops such as Canada and the US. Ways to come to a definition for environmental damage have been extensively discussed, although damage thresholds and clear criteria for or against commercialisation have not (yet) been specified. Definitions for environmental damage that are accepted by all European countries are still lacking.

As consequence, the precautionary principle as well as the dimension of uncertainty and ignorance must play an important part in the decision process concerning the admission, non admission of GMOs.