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Formulation of criteria for a sustainable and environmentally compatible use of genetically engineered crop cultivars

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Summary

Criteria for a sustainable and ecologically beneficial use of genetically engineered crop cultivars

Currently it is estimated that by the year 2000 more than six billion people, and by the year 2050 more than ten billion people will live on the earth. In order to meet the food requirements of this rapidly growing world population, agricultural production must be increased first of all by improving crop yields on the currently managed land areas. The United Nations Conference on Environment and Development held in Rio de Janeiro in 1992 has defined the concept of sustainability for agriculture. Concomitant to the need to increase the global food production, the main objectives are the preservation of natural resources and the maintenance of the environment.

The realisation of the concept of sustainable development in agriculture requires stepwise changes in production and consumption patterns in industrialised as well as developing countries. These changes also have to combine economic efficiency, fairness of allocation and environmentally tolerable utilisation of natural resources in order to meet the mutual benefits of each of the participating countries. **Sustainable agriculture** has the following objectives:

- Intergenerational equity: Future generations of mankind must have the same chances for their development as present generations.
- Preservation of resources: Soil, water and air must be maintained as the basis of production. In the long run, the exploitation of these resources should not exceed their capacity to regenerate.
- Biodiversity: The diversity of living systems should be preserved and utilised.

- Ecological responsibility: Natural ecosystems should not be impaired, i.e. the release of matter and materials and energy should not exceed the tolerance of the environment and its capacity for assimilation, respectively.
- Socio-economic responsibility: The capability of farms to exist should be maintained.
- Social responsibility: Agriculture guarantees the supply of food and ensures the quality of food.
- Global responsibility: All aspects mentioned above should equally be applied to a global scale.

It is expected that the first generation of genetically modified crop cultivars which will be cultivated on a large scale in Germany and in the European Union (EU), are characterised by resistance to herbicides, insects and viruses as well as by an optimised product quality for the use as industrial raw materials. On a global scale but especially in Germany there are only little relevant data available that allow an assessment of the ecological and economical sustainability of the cultivation of transgenic crops.

Within the countries of the EU the cultivation of genetically modified herbicide-resistant (HR) tobacco (Bromoxynil) and oilseed rape and radicchio (both glufosinate) for hybrid seed production is already legalised. Other crop species with transgenic **herbicide resistance** will get permission in the near future. Herbicide-resistant crop species are currently discussed controversially in the public, despite the fact that these transgenic crops open several possibilities for the application of ecologically more favourable cropping techniques. With the use of crops with a resistance against selective herbicides an improvement of late weed control in conventional cropping systems could be achieved and new environmentally more compatible cropping systems could be developed. Additional options for the use of herbicide-resistant crops are a better handling of inter-cropping systems for the annual row-crops maize and sugar beet, the cultivation of which quite frequently creates erosion and weed problems. Cropping systems utilising dead or living mulch-covers controlled by an herbicide provide possibilities for the application of conservation tillage to minimise soil erosion and an efficient control of weeds. Simultaneously, the risk of the development of herbicide-resistant weeds is minimised. The aim could be a vegetation management by regulating the soil cover instead of trying to control a weed flora which is developing in an unpredictable manner. The development of transgenic herbicide-resistant crops for regions with problems caused by parasitic weeds, such as *Orobanche*-, *Cuscuta*- or *Striga*-species, would contribute to a sustainable agriculture. Especially in ‘third world’ countries parasitic weeds so far impose unsolvable problems in plant production systems.

Non-selective herbicides should not be applied permanently and in large scale to main field crops because there is some evidence for the development of resistance against glyphosate, e.g. for a *Lolium*-species from Australia. Especially glyphosate with its systemic effect and short persistence in soil should mainly be applied at sites with special weed problems (e.g. quackgrass) in order to avoid a rapid loss of effectiveness due to the development of resistance. For this reason, not only complementary herbicides of transgenic plants but also a range of other herbicides should be applied for weed regulation.

Since 1997 transgenic maize with ***B.t.* insect-resistance** can be placed on the market within the countries of the EU. The resistance of transgenic crops against insects is based on the expression of insecticidal proteins (d-endotoxins) from the soil bacterium *Bacillus thuringiensis* (*B.t.*). These proteins have long been used as insecticides a.o. in biological farming systems. They are non-toxic for humans and other mammals and so far no negative effects on other biota and the environment have been reported. The toxic effect on some insects is specific. Under sunlight the *B.t.* d-endotoxins rapidly degrade into non-toxic metabolites. Due to these characteristics these insecticides are considered as ‘ecologically beneficial’.

If *B.t.*-toxins are applied at large scales to transgenic crops, the development of resistant insect populations is highly probable. Resistance has already been documented in field trials for the cabbage moth, and more than ten species became resistant against the toxin in laboratory selection experiments (a.o. Colorado beetle). These species developed resistance not only against a specific protein, but also against several different toxins. This example of cross-resistance against different *B.t.*-toxins clearly shows that the toxins can not simply substitute for one another. It is essential for sustainable crop production systems to maintain the effectiveness of these environmentally compatible insecticides. Therefore, it is necessary to develop resistance management strategies for the use of *B.t.* d-endotoxins expressing crop plants and to evaluate their efficiency and applicability under conditions of agricultural practices.

The first marketable crop cultivars with **resistance against viruses** are probably rhizomania-resistant sugarbeets and potatoes resistant to the most important potato viruses (PVX, PVY, and PLRV). Currently the use of conventionally bred rhizomania-tolerant sugarbeet cultivars already enables to avoid yield losses. However, an effective control of this disease is expected only by the cultivation of transgenic rhizomania-resistant cultivars. In particular, seed potato growers could benefit from genetically engineered virus-resistant potatoes. Seed production in potato would be less time-consuming, cheaper, and more environmentally compatible because the expensive control for virus infection and the routine use of insecticides to control virus vectors in certification programs would no longer be necessary.

There is a controversial discussion whether the incorporation of virus genes into plants could create new viruses with new characteristics (e.g. different host range, higher virulence) through heterologous encapsidation and recombination. So far, no new viral diseases have been reported from field tests with transgenic virus-resistant plants. Several measures, e.g. the use of short or defective viral sequences, are possible to minimise adverse consequences of recombination in future large scale use of transgenic virus-resistant plants. Such measures should be implemented in order not to counteract positive ecological and economic effects of transgenic virus-resistance by a potentially higher ecological risk.

Genetic engineering provides an approach for **optimising the quality of raw materials** of crops without ideally affecting other performance characteristics of the particular cultivar. Therefore, genetic engineering also enables the range of agricultural products to be broadened. One such possibility is to grow traditional crops as renewable resources which express a genetically modified quality (e.g. high-lauric rapeseed or amylopectin potato). Alternatively, 'exotic' species can be cropped that already express the preferred quality, but which need to be genetically adapted for stable growth and yield at non-typical sites (e.g. fungal-resistant, early-maturing high-oleic sunflowers). By increasing the range of their agricultural products, the individual farmers are able to respond more flexible to changing demands from the market. It would also contribute to sustainability to produce agricultural raw materials and products, respectively, at sites of their later consumption in order to avoid or to reduce transportation costs and connected negative impacts on the environment. The same holds true for optimising product quality, which contributes to save industrial processing costs and corresponding environmental impacts.

However, developing countries could loose their currency sources when agricultural raw products are produced at compatible prices in the industrial countries. The production of lauric acid from genetically modified oilseed rape instead of imported coconut or palm oil is an example for such a development. For a sustainable global development compensating mechanisms and measures must therefore be established. From the point of view of global food supply, however, the question is discussed if it is morally tenable to produce raw materials instead of food if one considers 14 % of the world population suffering from malnutrition already now. 'Nutrition by self-sufficiency' must be the long term objective especially for the underdeveloped countries.

The development of **hybrid systems** for plant breeding is a further application of genetic engineering. Hybrid cultivars are higher yielding in comparison to non-hybrid cultivars and are showing a higher stress tolerance due to their superior vitality. As a consequence these cultivars show a higher performance in particular at unfavourable sites and under unfavourable environmental conditions resulting in higher yields (e.g. 10 - 20 % for oilseed rape) and also enhanced yield stability. Due to the better and more secured utilisation of the yield potential of crop species the natural production factors water, soil, and nutrients can be used more efficiently and in an environmentally sound manner. Higher and more stable yields by the use of hybrid cultivars with the same input of resources are therefore important aspects of a sustainable crop production.

The Fourth Technical FAO-Conference on **Plant Genetic Resources** in Leipzig has emphasised the usefulness of plant genetic resources for sustainable agriculture and their significance for world food security. With modern biotechnical methods these resources can be efficiently evaluated and subsequently utilised in breeding programmes. In this way it may also be possible to enhance the biodiversity in agroecosystems by introducing new combinations of plant characteristics. Besides the protection of old cultivars, landraces, and wild relatives of cultivated crops, maintaining biological diversity in the form of genes and expression-specific promoters is a significant contribution to the future food security.

According to the authors' opinion, it is currently not necessary to extend the **principles of an orderly farming** and of a **good agricultural practice** with the expected incorporation of genetically modified crops into agricultural plant production systems. Such a need for action would exist when in the future

conventional cultivars will be displaced by e.g. HR- and *B.t.*-cultivars. For an evaluation of the possible agronomic and ecological consequences of the large scale cultivation of transgenic crops, reliable field data are lacking. For such an assessment long-term ecological research projects and long-term monitoring programmes, respectively, concomitant to the stepwise field release of crop species with particular transgenic traits are required.

By using genetic engineering, site-specific production techniques can be precisely supplemented and thereby optimised. Nevertheless, the demand for an orderly land use and an integrated production systems still remains. Only a well trained farmer can take the responsibility to choose the best cropping method for a specific site under the prevailing demand by the market. In the future, in order to have a selection of location adapted cultivars, the farmer must be able to chose from a wide range of cultivars of the various crops. The overall economic, social and cultural conditions of society will decide whether the aims of agricultural sustainability can be realised by the farmer.