Health-relevant and environmental aspects of different farming systems: organic, conventional and genetic engineering

Summary of the study entitled

Published by: InterNutrition - Swiss Association for Research and Nutrition, Switzerland
Author: Kurt Bodenmüller, Foundation **Gen Suisse**, Switzerland

InterNutrition, Zurich, September 2001

Table of Contents

---

1. Summary of the findings

1.1. Starting position and aims of the study

- For many consumers organic products have the reputation of being healthier, safer and better tasting than conventional foods, whereas genetically modified (GM) foods are often seen as unnatural, a threat to health or a potential risk to the environment. The key question in this study was whether these perceptions agree with scientific findings.

- A scientifically sound risk-benefit assessment leading to an objective discussion requires that the various agricultural production systems be objectively compared with each other instead of being individually assessed in isolation. Based on published scientific papers, InterNutrition presents a summary of the facts that must be taken into consideration when comparing organic, conventional and genetic engineering farming strategies.

1.2. The most important findings

- From a scientific viewpoint, organic foods are neither healthier nor safer than conventional or genetically modified products. Some studies show that organic foods may contain more fungal toxins than foods produced by conventional methods. Transgenic Bt (*Bacillus thuringiensis*) maize varieties, on the other hand, occasionally exhibit noticeably smaller quantities of mycotoxins in the kernels than conventional varieties do.

- In terms of nutritional composition and the effects on animal feeding, there are no significant differences between conventional and genetically modified feeds. Meat, milk and eggs from animals given GM feeds are just as harmless for human consumption as if they had come from animals fed on conventional feeds.

- The problem of cross-fertilization by pollen (gene transfer) between genetically modified plants and related wild species as well as between transgenic and conventional crop varieties only arises with few important species of cultivated plants. Detailed studies must be undertaken on a case-by-case, place-by-place, plant-by-plant and transgene-by-transgene basis. Growing crops by various agricultural systems side by side has always been possible and will continue to be so in future.

- The field studies carried out so far with transgenic, pest resistant crops do not confirm the environmental risks predicted by critics. For example, Bt maize varieties do not result in a temporary reduction in the number of beneficial organisms in the field, as can be observed with some synthetic pesticides.

- Already shortly after their introduction transgenic plants prove to be a valid option for a farming approach that sustains resources and protects the environment. The savings achieved so far in pesticide use and the improvements in ground flora and fauna can be ranked alongside the efforts of integrated production and organic farming on behalf of a more sustainable agriculture.

2. Statistics, developments and opinion polls

2.1. Statistics and the development of organic farming and the use of genetically engineered crops

- Organic agriculture has its origins in the first half of the 20th century with the establishment of bio-dynamic agriculture in 1924 and organic farming in 1940. By the year 2000 roughly 10.5 million hectares (26m acres) of agricultural land had been given over world-wide to organic farming. The global market volume of organically produced foods is estimated at just under $US 20 billion [1]. At the moment, organic products still only account for a small share of the overall market in all countries. According to an ITC study, the market for organic foods is growing fast in most industrialized countries - especially in Europe [2].

- The beginning of agricultural biotechnology dates back to 1983, when it first became possible to genetically modify a plant. In the year 2000 the area of land world-wide on which transgenic plants were being cultivated was approximately 44.2 million hectares (109m acres). The overall market for genetically modified plants was given as US$ 3 billion. Since its commercial introduction in 1996, the cumulative area on which transgenic crops have been grown is 125 million hectares (309m acres) - mainly in the United States, Argentina, Canada and China. Soya, maize (corn), cotton, rape and potatoes are among the most frequently grown GM crops [3].

Organic farming and genetically modified (GM) crops in comparison

Criterion	**ORGANIC***	**GM***
Beginning	2)	1983
Switzerland: area used for farming (2000)	85,000 ha	-
Switzerland: share of total area used for farming (2000)	8.1%	0%
Europe: area used for farming (2000)	3.5m ha	20,000 ha
Europe: share of total area used for farming (2000)	1.9%	0.02%
USA: area used forfarming (2000)	0.9m ha	30.3m ha
USA: share of total area used for farming (2000)	0.2%	7%
Global: area used for farming (2000)	10.5m ha	44.2m ha
Global: tendency compared with previous year (1999)	rising	rising
Global: market for transgenic plants (2000)	-	$US 3 billion
Global: market for organic foods (2000)	$US 19.7 billion	-

(* partly updated figures [1, 3, 4, 5]; [1)] bio-dynamic agriculture; [2)] bio-organic farming)

2.2. Surveys and public opinion polls on organic and genetically modified food products

- Various consumer surveys in Switzerland, the United Kingdom and the United States (1999/2000) present a uniform picture regarding the reasons for the purchase of organic foods. "Healthier", "safer", "better", and "more environmentally friendly" than conventional products were the arguments given (in order of importance).

- In comparison with United States consumers, those in Europe tend to be more sceptical towards genetically modified foods. According to the Eurobarometer survey, 59% of Europeans perceive GM products to be a potential risk [6]. On the other hand, only 2% of American consumers believe that GM foods represent a particular health risk [7].

- The widely held opinion that consumers in Europe do not want genetically modified products cannot be confirmed. Consumer confidence surveys showed that, for instance, 21% of Swiss consumers [8] and 48% of British consumers [9] wish to eat GM foods. In addition, 22% of the EU citizens who were interviewed would buy GM fruits, provided that these taste better than comparable conventional products [6].

3. Health-relevant aspects of human and animal nutrition

3.1. Comparison of nutritionally relevant constituents and qualitative characteristics of foodstuffs

- The comparison of organically and conventionally produced foods in more than 150 studies revealed that there are only very slight differences concerning their content of nutritionally and health-relevant constituents (vitamin, trace element, mineral, heavy metal, protein, starch and sugar content).

- It follows from the scientific papers published to date that organic products are neither healthier nor safer than conventional or genetically modified foods.

3.2. 3.2. Comparison of natural and chemical pesticides and their relevance to health

- Of the chemical substances that are ingested by human beings, 99.9% are of natural origin. The amount of synthetic pesticide residues taken in per person per day is roughly 10,000 times smaller than the daily dose of natural pesticidal substances produced by the plants themselves. Several of these natural pesticides are comparable with synthetic pesticides in terms of their toxicity and carcinogenic properties.

- Compared with microbial toxins or toxins occurring naturally in plants, the health risk posed to consumers by chemical pesticide residues is very low. The quantities of pesticide residues ingested by the European population are extremely small, often less than 1% of the daily acceptable intake, i.e. the amount that is deemed to be unproblematic in health terms. Therefore, the relevance to human health of synthetic pesticide residues should not be overvalued.

3.3. Mycotoxins in organic, conventional and genetically modified products

- Mycotoxins are poisonous by-products of the metabolic activity of fungi. Very small concentrations can endanger the health of both human beings and livestock, for instance by being carcinogenic.

- Occasionally, significantly higher mycotoxin concentrations were measured in various organic foods (apple juice, rye, wheat) than in conventionally farmed products. From such individual results no generalisations can be drawn except to reinforce the demand for stringent controls and further studies including organic products.

- Compared to conventional maize, the grains of genetically modified maize varieties may contain up to 90% lower concentrations of fumonisin and up to 75% lower aflatoxin concentrations. Smaller amounts of fungal toxins in Bt maize varieties constitute a verifiable health benefit for livestock and consumers.

3.4. Constituents of conventional and genetically modified animal feeds and their nutritional and physiological properties

- Numerous studies confirm that genetically modified animal feeds are equivalent to conventional feeds in terms of nutrient composition.

- Genetically modified and conventional animal feeds do not differ with regard to their effects on animal nutrition.

- Meat, milk and eggs from farm animals fed with GM feeds are just as safe for human consumption as products from animals given traditional feeds.

4. Environmental aspects of various agricultural systems

4.1. Pollen flow and gene transfer

- a) Gene transfer from transgenic plants to related wild species

  - Gene transfer from crops to related wild species by means of pollen is a natural process that occurs constantly and is well-known in conventional breeding. The crucial question is whether cross-fertilization partners are present locally and whether any progeny capable of reproduction can give rise to negative environmental effects.

  - The situation of crops and their wild relatives in Switzerland was described extensively by Ammann et al. in 1996. Various crops important for Switzerland have no related species for cross-fertilization (for example, maize, potatoes, soybean, tomatoes, sugar beet, barley and red clover) or are strict self-fertilizers (wheat, vines). In these cases, as well as in the case of vegetative reproduction or plant sterility, cross-fertilization by means of pollen is either impossible or highly improbable.

  - The fear that new, aggressive weeds could be created by genetically modified, herbicide tolerant plants has not so far been confirmed - as various field studies show. Outside the field where herbicides are not used, wild plants often lose any acquired herbicide tolerance within a few generations, without being able to spread.

  - It is important that clarification concerning cross-fertilization should be undertaken on a case-by-case, place-by-place, plant-by-plant and transgene-by-transgene basis.

- b) Gene transfer from transgenic plants to conventional crops

  - Likewise, pollen transfer from a field of genetically modified plants to a neighbouring field of organic or conventional varieties must be differentiated according to plant species. The extent of pollen flow does not correspond to the gene flow.

  - In the case of crops such as potatoes, which reproduce vegetatively, or sugar beet, which are harvested long before they blossom, gene transfer does not occur under Swiss cultivation conditions. In the case of self-fertilizers, such as wheat or barley, a separation between fields of only a few metres is sufficient to prevent cross-fertilization. Even in the case of maize, gene transfer is practically negligible when there is an isolation distance of about 100 metres. The problem of gene transfer by pollen is restricted to a few cross-fertilizing species, such as rape or rye, the pollen of which is durable.

  - Pollen transfer and gene flow also occur between conventionally and organically farmed fields. Despite this, various production systems (conventional, integrated, organic) have become established alongside each other in Swiss agriculture.

4.2. The effects on beneficial and other organisms in the field

- A laboratory study published in May 1999 showed that caterpillars of the monarch butterfly suffered damage following forced feeding with Bt maize pollen. This study gave rise to great concern regarding the environmental risks of genetically modified plants and led to a suspension in the licensing of transgenic, insect resistant crops within the EU. Subsequent field studies showed, however, that Bt maize varieties do not pose a threat to the monarch caterpillar and that its negative effects on the insect, if any, are extremely slight. This example illustrates how important it is that results obtained under laboratory conditions should be checked by carrying out appropriate field studies in order to gauge the actual field situation.

- None of the studies of genetically modified, insect resistant Bt maize varieties carried out under realistic cultivation conditions has confirmed the predicted dangers to beneficial and other so-called non-target organisms. On the contrary: comparative field studies have shown that the application of various chemical pesticides is more harmful to some of the insect populations studied than the use of GM crops.

4.3. Comparison of various control strategies to combat fungal diseases

- Fungal diseases represent a serious agricultural problem for potatoes, vines, fruits, and cereals. During wet weather, in particular, fungi can cause serious crop damage.

- Whereas farmers using conventional or integrated production can call on a whole range of fungicides (chemical fungus control agents), organic farmers mainly use inorganic copper- and sulphur-based products. In Switzerland this often involves 4 kilograms of pure copper per hectare annually (almost 3.6 lbs per acre). Copper accumulates in the soil and, in the long term, makes it infertile.

- For many years research involving transgenic breeding methods has been carried out in order to find sustainable alternatives to chemical fungus control. As a result of genetic engineering, a plant's own resistance genes can be identified and natural protective mechanisms explored. Other research projects concentrate on the transfer of fungus resistance genes (for example, enzymes such as chitinase) to major crops. The first GM varieties to possess increased disease resistance are about to be tested in field trials under realistic cultivation conditions. Compared to classic cultivation methods, plant breeding by genetic engineering opens up new possibilities that will soon make it possible to offer farmers varieties that have better fungal resistance, thus enabling the spread of environmentally friendly farming.

4.4. The environmental benefits of organic farming and agricultural biotechnology

- Organic farming is characterized by more extensive cultivation of the land, reduced use of chemical pesticides and fertilizers, and the encouragement of mixed farms (arable and livestock farming). According to various studies, organic farming has more positive effects on natural soil fertility (higher organic content, lower soil acidity, better soil structure and activity, more soil fauna), and a greater diversity of animals, plants and microorganisms than integrated production does.

- In the case of commercially licensed genetically modified plants of the first generation, considerable savings of chemical pesticides represent the major environmental benefit. In the United States, the cultivation of transgenic Bt cotton varieties resulted in roughly one million kilograms of conventional insecticide being saved between 1996 and 2000. Bt maize varieties have demonstrably fewer negative effects on beneficial organisms than various synthetic pesticides. By growing transgenic, herbicide tolerant soybean varieties in North America - and using environmentally friendly active substances -the average reduction of herbicide applications was between 10% and 20% (in some cases up to 50%). A Danish study published in February 2001 showed that the cultivation of transgenic, herbicide tolerant sugar beet led to a more diverse accompanying weed flora and greater insect diversity than conventional beet cultivation [10].

4.5. Agricultural yields and world food security

- One of the most important objectives of farming is the sustainable increase in agricultural yields. The use of hybrid varieties and synthetic nitrogen fertilizers in recent decades has led to a massive increase in crop yields and a reduction in food prices. The green revolution has resulted in the percentage of the world's population suffering from hunger dropping from 50% in the year 1960 to 20% (or 800 millions) today. Because the global population continues to increase rapidly, an additional 1.5 billion people must be fed by the year 2020 - although the area of available arable land per head is decreasing.

- Genetically modified, disease and pest resistant as well as drought or salt tolerant plants have the potential to make an important contribution to cope with this challenge. The improvement in the quality of major crops is another goal of transgenic breeding methods. It is hoped that the so-called "golden rice" which contains provitamin A in the grains, will one day make a contribution to lowering the incidence of diseases associated with vitamin A deficiency in developing countries.

- In organic farming, yield losses of between 10% and 40% are accepted (on average 20%). By relying solely on this form of farming, which prohibits the use of synthetic nitrogen fertilizer, a maximum of four billion of the world's six billion people could be adequately fed.

5. Conclusions

- The farming methods available today (organic, integrated and conventional, genetic engineering) all have their advantages and disadvantages. A direct comparison of the benefits and risks of the various systems and their products is only possible to a limited extent because of the lack of comparative studies. More research is necessary in this field in order to confirm previous results and to obtain reliable findings.

- Since their introduction, genetically modified products have been subject to stricter safety regulations and are among the best analyzed of all foods. Their safety in terms of human health must be scientifically verified before their introduction to the marketplace. In the interests of consumer health, organic products and conventional foods should be subject to the same rigorous safety analyses as those that apply to GM products.

- From agronomic, health and environmental viewpoints, conventional, organic and genetic engineering farming methods should coexist. The different strategies help move towards a more sustainable agriculture. Only a flexible and specific combination of all useful approaches will enable the existing potential to be fully exploited.

- An unilateral ban on transgenic breeding methods cannot be scientifically justified. It would be incomprehensible and short-sighted not to benefit from these new opportunities in order to overcome unsolved agricultural problems.

6. References

1. Willer H., Yussefi M. 2001. Organic Agriculture Worldwide 2001 - Statistics and Future Prospects. SÖL-Sonderausgabe Nr. 74. Stiftung Ökologie & Landbau, Bad Dürkheim, Deutschland.

2. Kortbech-Olesen R. 1999. Organic Food and Beverages: World Supply and Major European Markets. International Trade Centre UNCTAD/WTO (ITC), Geneva, Switzerland.

3. James C. 2000. Global Status of Commercialized Transgenic Crops: 2000. ISAAA Briefs No. 21. ISAAA, Ithaca, New York, USA.

4. **http://www.transgen.de/**

5. **http://www.bio-suisse.ch**

6. INRA (EUROPE) - European Coordination Office. 2000. Eurobarometer 52.1 - The Europeans and Biotechnology. Directorate-General for Education and Culture "Citizens' Centre", Brussels, Belgium.

7. International Food Information Council (IFIC). 2001. U.S. Consumer Attitudes Toward Food Biotechnology, Washington D.C., USA.

8. Longchamp C. 2000. Gentech-Akzeptanz zwischen Optimismus und Pessimismus. GfS-Forschungsinstitut, Bern, Schweiz (**http://www.gfs.ch/publset.html**).

9. Survey into GM foods. 2001. NOP Research Group, London, UK (**http://www.cropgen.org/**).

10. Elmegaard N., Bruus Pedersen M. 2001. Flora and Fauna in Roundup Tolerant Fodder Beet Fields. NERI Technical Report No. 349. National Environmental Research Group, Silkeborg, Denmark (**http://www.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR349.pdf**).

For the complete reference list, see the German version of the full study.