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GENETICALLY MODIFIED ORGANISMS: POTENTIAL HEALTH CONSEQUENCES

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Abstract: Now 372 lines of transgenic plants have been developed from 27 varieties and are approved for commercial use. Some negative (carcinogenic, etc.) GMO effects on mammals are noted by a few researchers. But such „sensational" experiments are negligible compared with the research which proves GMO safety.

Key words: transgenic organisms, DNA biotechnology, biosafety, negative GMOs effects

Introduction

Recombinant DNA technology, as a basis of modern biotechnology, was developed in 1972 [1], and the first transgenic organisms (plants and animals) were developed with this technology in 1982. According to the Article 3i of the Cartagena Protocol on Biosafety to the Convention on Biloloigical Diversity [2], modern biotechnology means the application of:

a) in vitro nucleic acid technique including recombinant deoxyribonucleic acid (DNA) and direct injection of nucleic acid into cells or organelles, or
b) a fusion of cells beyond the taxonomic family, that overcomes the natural physiological reproductive or recombination barriers and that are not techniques used in traditional breeding and selection.

Now genetically modified microorganisms are widely used in the pharmaceutical industry, producing human insulin (diabetes), interferon (viral infection), somatotropin (ateleiosis), etc. The first transgenic plants were developed with recombinant DNA technology in 1982 by scientists from the Institute of Plant Industry in Cologne (Germany) and the biotech concern Monsanto (USA). 2014 marked an unprecedented 100-fold increase in transgenic plants (or biotech crop) hectarage from 1.7 million hectares in 1996 to 181.5 million hectares (> 12% of the planet's farmlands). As for animals, it should be noted Belarusian and Russian researchers have developed transgenic goats producing human lactoferrin as raw material for nutritional compounds and anticancer drugs.

These microorganisms and animals are not of great public concern compared with the widespread use of transgenic plants which is of great public concern. In Europe, there are even zones free from GMOs, and congresses of such zones representatives have been regularly held [3].

Transgenic Plants in the World

According to the International Service for the Acquisition of Agri-biotech Applications (ISAAA) [4], the USA retains leadership (73.1 million hectares in 2014), the five lead developing countries in biotech crops are China and India in Asia, Brazil and Argentina in Latin America, and South Africa on the continent of Africa, collectively grew 78.2 million hectares (46% of global) and together represent ∼40% of the global population of 7 billion.

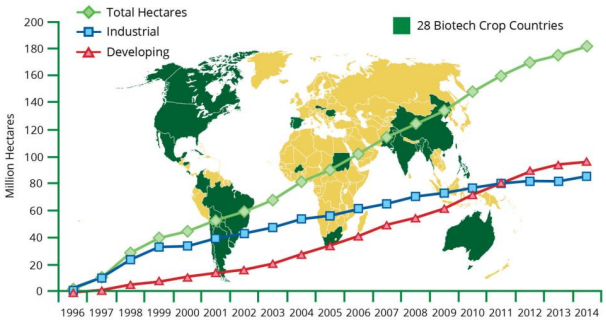

Fig. 1: Global Area of Biotechnological Crops (1996–2014) [4].

Two new countries, Sudan (Bt cotton) and Cuba (Bt maize), planted biotech crops for the first time in 2012. Germany and Sweden could not plant the biotech potato, Amflora, because it has ceased to be marketed; Poland discontinued planting Bt maize because of regulation inconsistencies in the interpretation of the law on planting approval between the EU and Poland. One new country Bangladesh, planted biotech crops (brinjal/eggplant) for the first time in 2014. The whole list of biotechnological countries is presented in Table 1.

Now 372 transgenic plant lines, developed from 27 varieties, are permitted for commercial use: tomatoes, eggplant (since 2013), potatoes, rice, sugar beet (since 2013), sugar cane, flax, turnips, melons, beans, sweet pepper, tobacco, chicory, papaya, carnations, wheat, lucerne, creeping bentgrass, plum, sunflower, rose, and poplar [5].

Table 1: Biotechnological Countries and Transgenic Plants Cultivated [4].

Country	Area (million hectares)	Biotech Crops
USA*	73.1	Maize, soybean, cotton, canola, sugarbeet. alfalfa, papaya, squash
Brazil*	42.2	Soybean, maize, cotton
Argentina*	24.3	Soybean, maize, cotton
India*	11.6	Cotton
Canada*	11.6	Canola, maize, soybean, sugar beet
China*	3.9	Cotton, papaya, poplar, tomato, sweet pepper
Paraguay*	3.9	Soybean, maize, cotton
Pakistan*	2.5	Cotton
South Africa *	2.7	Maize, soybean, cotton
Uruguay*	1.6	Soybean, maize
Bolivia*	1.0	Soybean
Philippines*	0.8	Maize
Australia*	0.5	Cotton, canola
Burkina Faso*	0.5	Cotton
Myanmar*	0.3	Cotton
Mexico*	0.2	Cotton, soybean
Spain *	0.1	Maize
Colombia*	0.1	Cotton, maize
Sudan*	0.1	Cotton
Honduras	< 0.05	Maize
Chile	< 0.05	Maize, soybean, canola
Portugal	< 0.05	Maize
Cuba	< 0.05	Mai re
Czech Republic	< 0.05	Maize
Romania	< 0.05	Maize
Slovakia	< 0.05	Maize
Costa Rica	< 0.05	Cotton, soybean
Bangladesh	< 0.05	Brinjal/Eggplant

* 19 biotech mega-countries growing 50,000 hectares, or more, of biotech crops. Meanwhile soybean, maize, Polish canola, Argentinean canola, and cotton occupy 98.8% of all areas under transgenic plants [4]. Furthermore soybeans contain 82% of genetically modified material, and corn has 30% (Figure 2).

GMO and Health

The probable negative effects of GMO on human health and the environment can be caused by:

- The fact that the alien DNA insertion can be fraught with:

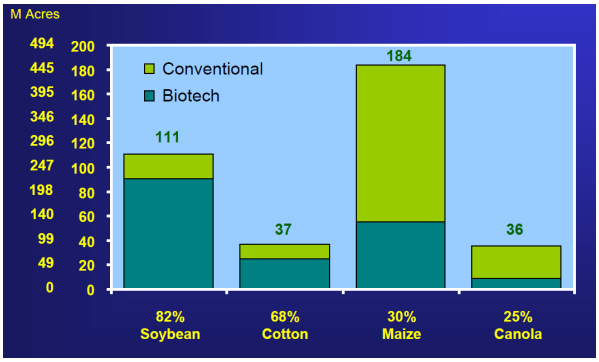

Fig. 2: Main Transgenic Crops (percentage of conventional and biotechnological variants) [4].

  - changes in the activities of some genes of the recipient organism;
  - the appearance of the possibility to transfer transgenes into other organisms.
- The syntheses of proteins – transgene products, new for the recipient organism, which can be toxic and/or allergenic for the other organisms [6].

For the first time the negative effects of GMOs on mammals were noted by British biochemist Arpad Pusztai, a Hungarian-born (The Rowett Institute, Aberdeen, Scotland). He studied the effect of genetically modified potatoes with the addition of the snowdrop lectin gene (a natural insecticide, safe for mammals) in rats and found painful changes in their body, dysfunction of some organs and immunity disorders. He announced his conclusions about the harmful effects of transgenic food on health in a popular TV show (August 10, 1998). The telecast roused a keen response, A. Pusztai was fired from the institute, as he himself says, in connection with his statement. However, the dismissal did not prevent him from publishing the results of the research in the journal „The Lancet" together with Stanley Yuen [7]. And A.Pustai's opponents consider that his research has just proved the fact that if you feed the animals with poison, they will get sick and die.

However, in the literature there are reports of adverse effects of feed, which contained, for example, soybean line 40-3-2 [8], maize lines MON 810 [9–11] and MON 863 [12, 13]. We, for the sake of objectivity, will consider some of these results.

In Russia and other NIS countries, Moscow neurophysiologist I.V. Ermakova discussed GMO effects most widely. Since 2005, she has been engaged in an experimental study of the effect of genetically modified soybean (RR, line 40.3.2) on the health of rats and their offspring. In her opinion GM soybeans affect the genitals and reproductive functions of animals, leading to hormonal imbalance, infertility and tumor formation, underdevelopment,

etc. Her results, published in the journal *Nature Biotechnology*, aroused the interest of scientists from around the world and were the subject of widespread criticism that continues to this day.

Autumn 2012 was marked by the publication of sensational results of Gilles-Éric Séralini, professor of molecular biology at the University of Caen (Lower Normandy) [14]. His group, in complete secrecy, had investigated the long-term effects of genetically modified maize NK 603. A year after the start of the study the rats, which were fed with genetically modified feed, had abnormalities and severe pathology. Many females had a breast tumor, in some cases up to 25% of the body weight, while males had abnormalities in the liver and kidneys. All these diseases occurred 2–5 times more often in these animals than in those fed with conventional maize.

In France, the results of experiments were tested by the Supreme Council for Biotechnology (Haut Conseil des Biotechnologies, HCB) and the National Agency for Sanitary Security of Food, Environment and Labour (L'Agence Nationale de Sécurité Sanitaire de l'Alimentation, de l'Environnement et du Travail, ANSES). The HCB report indicated that „the very design of the study, methods of statistical analysis used by the author, and their interpretation are characterized by a clear lack of data and methodological errors unacceptable." The ANSES report noted that the results obtained by Mr. G.-É. Séralini do not give him a basis for the statements made at the press conference at the European Parliament. However, both French governmental agencies recommended additional studies of products containing GMOs.

In December 2012 the work of expert committees set up in six countries Belgium, Denmark, France, Germany, Italy and the Netherlands – was summed up in Parma at the headquarters of the European Food Safety Authority (EFSA) [15]. All the comments are in one place on 157 pages and made public on the EFSA website. The general conclusion is that the article can not be substantiated due to the design of experiments, analysis of the results (especially statistics), or discussion of the findings. G.-É. Séralini agreed that his design is not suitable for the evaluation of carcinogenicity, and he also could not give a clear answer, whether the calculations of the required number of animals were really made before the experiment began.

From recent publications a review [16] should be noted. This review discusses both arguments of GMOs opponents and much more numerous articles demonstrating the safety of transgenic soybean and corn long-term consumption by laboratory animals – mice and rats.

Testing of Products for GMOs Presence

The requirement for labeling products containing GMO logically follows from the basic principle of the Cartagena Protocol on Biosafety – the precautionary principle and carried out in countries with a developed system of biosafety (the EU states, Japan, the Republic of Belarus, and others).

The criteria for the labeling of raw materials and food products containing GMOs are different in the national legislation of different countries. As a rule, there are legislated limits above which food and feed must be labeled with the words that they are made of transgenic crops or using genetically modified ingredients.

The European Union legislation admits the absence of labeling if the product contains less than 0.9% of GMOs ingredients [17]. When determining the safety of foods containing GMOs, most countries use the principles recommended by the EU in 1998 [18]. However, the labeling level is different in: Japan obliges labeling of products containing 5% or more of genetically modified ingredients, South Korea – 3%, Australia – 1%. It should be emphasized that the choice of a specific percentage of the value as a threshold for the labeling is not related to product safety, and it is purely an administrative decision.

Currently, Belarus, as well as the EU and Russia, use the 0.9% threshold for labeling. To organize GMO control there are 18 testing laboratories in the Republic, of which the Ministry of Health – 6, the State Committee for Standardization – 8, the National Academy of Sciences of Belarus – 2 (one of them at the Institute of Genetics and Cytology as an organization carrying out the functions of the National Co-ordination Biosafety Centre), the Ministry of Agriculture and Food – 2. There is a list of laboratories accredited for GMO detection in Belarus: *Ministry of Public Health*

1. Republican Centre for Hygiene, Epidemiology and Public Health
2. Republican Scientific and Practical Centre for Hygiene
3. Minsk City Centre for Hygiene and Epidemiology
4. Brest Regional Centre for Hygiene, Epidemiology and Public Health
5. Gomel Regional Centre for Hygiene, Epidemiology and Public Health
6. Grodno Regional Centre for Hygiene, Epidemiology and Public Health
7. Mogilev Regional Centre for Hygiene, Epidemiology and Public Health
8. Vitebsk Regional Centre for Hygiene, Epidemiology and Public Health

State Committee for Standardization

10. Belarusian State Institute for Metrology

11. Brest Centre for Standardization, Metrology and Certification
12. Gomel Centre for Standardization, Metrology and Certification
13. Grodno Centre for Standardization, Metrology and Certification
14. Mogilev Centre for Standardization, Metrology and Certification
15. Vitebsk Centre for Standardization, Metrology and Certification

National Academy of Sciences

16. Institute of Genetics and Cytology (LDGMO)
17. Scientific and Practical Centre for Food

Ministry of Agriculture and Food

18. Belarusian State Veterinary Centre
19. Central Research Laboratory of Bakeries

During its existence, LDGMO conducted more than 25 thousand tests for the presence of GMO in food samples containing soybean and corn. The results are summarized in Table 2.

Table 2: Data on Testing Foodstuffs for Genetically Modified Content in LDGMO (2006–2015).

Year	Number of tests		Positive results
	Total	Positive (soybean – S, maize – M	
2006	312	6S	1.92 %
2007	1746	16 (15C+1M)	0.92 %
2008	3166	58 (47S+11M)	1.83 %
2009	3482	41 (37S+4M)	1.18 %
2010	3427	9 (7S+2M)	0.26 %
2011	2803	6S	0.21 %
2012	3291	4 (3S+1M)	0.13 %
2013	2779	43 (39S+4M)	1.55 %
2014	2474	26 (23S+3M)	1.05 %
2015	1542	24S	1.56 %
In Total	25022	233 (207S + 26M)	0.93 %

Conclusions

The first transgenic organisms were developed with recombinant DNA technology in 1982. Now genetically modified microorganisms are widely used in the pharmaceutical industry, producing human insulin, interferon, growth hormone, etc. As an example of genetically modified animals we can note the research of Belarusian and Russian scientists that developed transgenic goats producing human lactoferrin as raw material for nutritional compounds and anticancer drugs. All these achievements have been developed in close technological systems and do not cause fear among the public. Regarding transgenic plants, now 372 lines are developed from 27 varieties and are approved for commercial use. That is why the public is concerned about the probable negative effects of GMO on human health.

Some negative (carcinogenic, etc.) GMOs effects on mammals are noted by A.Pusztai (UK), I.B.Ermakova (Russia), G.-É.Séralini (France) and by a few other researchers. But, on the whole, such «sensational» experiments are scarce and are contradicted by the research work which proves GMO's safety, and the researchers themselves are usually rather cautious in their conclusions. However, the mass media picks up any „hot topic" on GMO's danger and exaggerates it in every possible way, replicating from newspaper to newspaper, from one site to another (frequently even with the same errors and inaccuracies).

Thus, the real evidence-based reasons for the categorical rejection of transgenic organisms are not currently available. Fears are caused by the fact of the invasion to the „holy of holies" of living organisms – their heredity. That is why the creation, release into the environment and commercialization of GMOs should be under strict national and international supervision.

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