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REVIEWS

Current Trends in the Global Market of Transgenic Plants and Environmental Safety Issues

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Abstract—The world market for the first generation of transgenic crops (insecticidal and herbicide-resistant plants) has been expanding since 2012, mostly owing to developing countries. The cautious attitude in the majority of economically developed countries to the first-generation transgenic agricultural crops is due to several objective circumstances: the negative impact of insecticidal Bt-crops on useful and endangered invertebrate species, the allergenic properties of Bt-toxin for humans, toxicity of glyphosate to humans and animals, the widely spreading resistance of weeds to glyphosate, the increasing resistance of "harmful" insects to insecticidal Bt-plants, the danger of "genetic pollution" of aboriginal plant varieties, and the flow of herbicide resistance traits to weed plants.

Keywords: *Bacillus thuringiensis*, transgenic plants, Cry-proteins, glyphosate, possible ecological risks

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INTRODUCTION

Transgenic plants have been used in industrial agriculture for nearly 20 years. In 2014, the world's arable lands amounted to 1.5 billion hectares; 181.5 million hectares (12.1%) of this area were allocated to crops of genetically modified (GM) plants in 28 countries, including eight developed countries. In 2013, Egypt left the "club of transgenic countries," whereas Bangladesh became a member in 2014 [1–3].

Over the past two decades, the public image of GM plants has changed considerably. In the 1990s, at the beginning of the advertising campaign for introduction of GM plants into production, they were positioned as the future of biotechnology. These plants were expected, on the one hand, to increase the crop yield and, on the other hand, to minimize environmental damage: insecticidal plants (Bt-crops) were considered as the means to restrict the use of pesticides, whereas the herbicide-tolerant crops were intended for the use in combination with an "environmentally safe" herbicide, glyphosate. Because of their "environmental safety" the first-generation transgenic plants became actively introduced into production, primarily in economically developed countries.

TRENDS IN DEVELOPING THE GLOBAL MARKET OF INSECTICIDAL Bt-PLANTS

Bt-plants are genetically modified plants that contain δ-endotoxin-encoding genes of gram-positive aerobic spore-forming bacterium *Bacillus thuringiensis*. The δ-endotoxins represent a class of numerous Cry- and Cyt-proteins capable of lysing cells of the intestinal tract in larvae of various insect orders. Permissions for the industrial use of Bt-crops were based on the declared specificity of action of Cry-proteins and on the assumption of limited spatiotemporal occurrence of Cry-proteins in secondary products outside the living plants.

A long-standing reason to claim ecological safety of Bt-toxin usage in plant protection was that the lethal effect of Cry-proteins is highly specific: the toxins belonging to one family were supposed to impact only representatives of one insect order. Over many years, there was an ongoing search for the new Bt-toxins and, at the same time, the testing of toxin effects on different insect species (in total, 125 out of 174 known Cry-proteins were tested). These tests revealed an unpleasant surprise: it turned out that 17% of Bt-toxins have sublethal and even lethal effects on representatives of "non-target" insect orders [4]. For example, the Lepidoptera-specific protein Cry1Ab was found to exert lethal and sublethal effects on Trichoptera (caddis flies) [5, 6], Coleoptera [7, 8] and Hymenoptera [9, 10]. Moreover, Cry-proteins exert a sublethal effect not only on the class of insects (Insecta) but also on representatives of

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Abbreviations: GM—genetically modified (plants); POEA—polyoxyethyleneamine.

the class Crustacea [11] and even segmented worms (Annelida) [12] and mollusks (Mollusca) [13].

It is obvious that *Cry*-genes in Bt-plants are genetically engineered products; they directly encode toxins rather than prototoxins encoded by corresponding native genes of the bacterium *B. thuringiensis*. The prototoxins are converted into toxins after processing by the enzymes in the larval digestive tract of the target insects. Therefore, Cry-proteins of Bt-plants should be considered as xenobiotics, i.e., substances that enter the environment only because of genetic engineering. For this reason, the "natural background" of Bt-toxins (Cry-proteins) never existed; accordingly, the living organisms possess no natural defense mechanisms (except for the aforementioned proteolytic activation of prototoxins). The possibility of synergistic action of Cry-proteins, other xenobiotics, and biologically active substances is particularly dangerous. For example, the "alarm substance" released by stickleback fish that triggers the response in daphnia (*Daphnia magna*) to predators was found to enhance the toxic effect of Cry1Ab-protein and to retard the rate of population growth [11].

Among the Bt-crops cultivated on an industrial scale, Bt-maize represents the greatest danger to beneficial and endangered insect species. This is because maize, unlike other insecticidal Bt-plants (cotton, and rapeseed) is wind-pollinated. Therefore, the range of insects feeding on its pollen is significantly wider, not to mention the fact that maize produces much more pollen capable of spreading over large distances. Amounts of Cry-proteins released into the environment by wind-assisted dispersal of Bt-maize pollen are rather large. For example, a 1 ha of Central European field where Bt-MON810 maize variety is grown releases into the environment 35 kg of pollen over the flowering period, comprising 4 mg of Cry1Ab toxin [14, 15]. In general, Bt-maize plants produce Cry-proteins in amounts that are 1500–2000 times higher than those sprayed during a single field application of Bt-toxin-containing chemicals, e.g., DIPEL.

There was a long-term belief, employed by the company Monsanto for the assessments of environmental risks, that despite the wind-promoted increase in the dispersal radius of maize pollen the major part of pollen is deposited on the same field and 98% of the pollen does not cover a 50-m distance beyond the field boundaries. However, it turned out later that the above assessments of the pollen dispersal are too optimistic and far from reality, because they did not take into account many factors, such as physical dimensions of a maize field, atmospheric turbulence, air convection caused by high summer temperatures, etc. Studies performed in 2007–2008 in the nature reserve Ruhlsdorfer Bruch (State Brandenburg, Germany), surrounded by fields of maize (including the Bt-maize variety MON810), showed that only a buffer zone of at least 1000 m wide can eliminate with a probability of 90% the chance of deposing of >100000 transgenic pollen grains per square meter of the protected area [16]. Subsequent long-term studies of maize pollen dispersal in Germany have shown that pollen shed may occur in the amount of several thousand grains per square meter even at a distance of a few kilometers from the maize fields, thus posing a threat to beneficial and endangered insects [17].

The fate of endangered butterfly species is a matter of concern because of the mounting observations that the pollen of major varieties of transgenic Bt-maize (Bt11, Bt176, and MON810) has a negative impact on lepidopteran larvae. The first studies of this issue appeared already in the end of the last century and were dictated by the concern for the safety of the monarch butterfly *Danaus plexippus* (Nymphalidae) in America [18]. The range of distribution of *D. plexippus* comprises the so-called "Corn Belt" covering a significant part of the midwestern United States. The caterpillars feed on *Asclepias* milkweed plants that grow in close proximity to or directly on maize fields. The pollen grains of flowering Bt-maize were a matter of concern, because these grains cover milkweed leaves and are eaten by monarch butterfly caterpillars. Studies have shown that feeding of *D. plexippus* larvae with the pollen of all three lines tested had a negative impact on the ontogeny and behavior of the larvae. In the case of line Bt176, the death of half of the population was observed after consumption of 13 to 36 pollen grains (depending on the larva age). The concentration of protein Cry1Ab in the pollen of maize variety Bt176 was found to be one or two orders of magnitude higher than in varieties Bt11 and Mon810. Consequently, the variety Bt176 was removed from production.

While assessing the negative influence of growing transgenic crops, many researchers did not take into account the phenomenon of zoophytophagy. This phenomenon is observed in some predatory insects, specifically, in the larvae of ladybirds (Coleoptera: Coccinellidae) that temporally switch from animal to plant food sources. A negative impact (retarded development) was first shown with ladybird *Propylaea japonica* larvae feeding on pollen of Bt-cotton (Cry1Ab) [19]. The laboratory experiments also revealed the increased mortality (50%) of the ladybird *Adalia bipunctata* larvae that received food containing Cry1Ab at doses comparable to the concentration of this Bt-toxin in the pollen of transgenic maize MON810 [7, 8].

Because of the fears for the fate of endangered and useful insect species, some European countries (Germany, Hungary, Austria, Sweden, Poland, and Greece) have banned the cultivation of Bt-maize line MON810.

Table 1. Proportion of GM-crops in the global arable land area in 2013/2014 [1, 3]

Crop	Crop area, million hectares	Area of GM-crops, million hectares	Proportion of GM crops, %	Number of countries adopted GM crops
Soybean	107.0/111.0	84.5/91.0	79/82	11
Cotton	34.1/37.0	23.9/25.2	70/68	15
Maize	177.0/184.0	56.6/55.2	32/30	17
Canola	34.0/36.0	8.2/9.0	24/25	4

Non-target effects of Cry-proteins are increased by their persistence in the environment. Because of the increased (by 10–66%) lignin content in stems and leaves of Bt-crops (a consequence of the pleiotropic effect of *Cry*-genes), the decomposition of these plant materials is very slow. In fact the degradation of Cry-proteins, which proceeds during decomposition of crop residues and continues in soil or on soil surface, may last from several months to one year [20, 21].

A similar situation develops in freshwater ecosystems. A large-scale examination for the content of Bt-toxin was conducted in 217 biotopes of streams and rivers flowing through the State of Indiana, which is a part of the aforementioned "Corn Belt." The study was conducted 6 months after the harvest of maize; the materials were sampled synchronously in one day at all sampling sites (May 16, 2007). In 13% of the biotopes examined (28 out of 217), the maize detritus of the previous year (2006) contained appreciable amounts of the protein Cry1Ab. However, the number of biotopes where Cry1Ab was detected in water (50 out of 217) was nearly two times higher than the number of habitats where Bt-toxin was detected in the detritus. In three cases out of four, when the transgenic detritus was present at the bottom of water body, the protein Cry1Ab was also detected in water [22].

The above studies, shedding new light on environmental effects of the cultivation of insecticidal crops, have found their reflection in the agricultural statistics: the areas under Bt-crops underwent reductions by 1–2 million hectares in 2000–2001, 2008, and 2011. For the sake of fairness, it should be noted that these three drops in the Bt-crop market were counterbalanced by its subsequent growth. Another decline in the proportion of insecticidal varieties of cotton and maize (Table 1) occurred in 2014. It should be pointed out that the cultivation areas under Bt-maize declined also in absolute values. Such a reduction in cultivation areas of insecticidal crops was largely due to widely spreading mutations of resistance to Cry-proteins in populations of phytophagous insects. For the 17-year period (from 1996 to 2013) when the Bt-crops were used on an industrial scale, eight agricultural pests developed resistance to Cry-proteins. Considering that some pests adapted to two Bt-toxins or, admittedly, to one Bt-toxin but in different parts of the crop distribution area, it is evident that at least fourteen cases of evolved resistance to insecticidal cotton (eight) and maize (six) were recorded. In six reported cases, the resistance mutation spread so widely that more than 50% of the larval population survived in the Bt-crop fields, causing considerable economic damage [23, 24].

Serious problems that arise from the introduction of new lines of insecticidal crops on the global market can be illustrated with in an example of Bt-eggplant. The main damage to this culture (crop yield losses of 51–73%) in southern and southeastern Asia is caused by an eggplant and shoot borer moth, *Leucinodes orbonalis*. The eggplant in these regions is second to cotton in terms of pesticide application. The number of treatments varies from 20 (India) to 80 (Bangladesh). The attempts to create a Bt-eggplant (Bt-brinjal) began in 2003 as part of a public–private partnership involving Cornell University (Ithaca, NY), the United States Agency for International Development (USAID), and the biotechnology corporation Monsanto on the part of the United States. On the part of India, Philippines, and Bangladesh, the venture involved the biotechnology corporation Mahyco. The Bt-brinjal was developed in 2009, but this GM crop was permitted only in Bangladesh for commercial use [25]. The ongoing mass protests in India and Philippines against Bt-brinjal were caused by the concerns that this food crop contains the gene *Cry1Ac* encoding a protein with two amino acid sequences shared with the three allergens (Cup a 1, Jun a 1b, and Jun o 1) that are present in the pollen of juniper (*Juniperus virginiana*). This fact suggests that Cry1Ac protein is a potential allergen. It should be noted that Bt-eggplant is the only transgenic food crop containing the gene *Cry1Ac*. Earlier, the transgenic rice containing this gene was banned in China.

In 2014 in Bangladesh, Bt-eggplant was sown by 120 farmers on an area of 12 ha, while the total area under eggplant was 50 000 ha. Although the seeds were distributed almost free of charge, there was no further expansion of the area under Bt-eggplant in the country, because almost all crops were damaged by a bacterial wilt disease. According to the official version, the mass destruction of crops was caused by violated timing of sowing [25]. But, in our view, another explanation is likely. The causative agent of wilt is a gram-negative bacterium *Erwinia tracheiphila* which is transmitted by phyllophagous beetles. After feeding on eggplant leaves infected with bacteria, the beetles act as carriers of *E. tracheiphila*. The bacterium survives in the insect gut for a few months, and the infection of new plants occurs during feeding of beetles on healthy leaves. It is possible that Bt-eggplant, compared to conventional eggplant varieties, became more attractive to phyllophagous insects, like the Bt-cotton became more attractive for aphids in China.

ENVIRONMENTAL RISKS OF GM CROPS WITH HERBICIDE TOLERANCE TRAITS

As the planting areas under Bt-crops were expanding and the data concerning negative impacts of Bt-toxin on nontarget invertebrates were mounting [19, 26, 27], the biotechnological corporations put forward a marketing slogan “two in one” in an attempt to promote the market of GM crops containing two genetically engineered traits (insecticidal action and herbicide tolerance). The use of these traits was publicly presented as a “green” biotechnology. In 2007, the areas under these crops became equal to the areas under insecticidal crops; in 2014 these dual-trait crops occupied the second place (51 million hectares, i.e., 28%) after herbicide-tolerant GM crops (102 million hectares, 55%) [3].

The environmental effects of herbicide-resistant GM crops are primarily associated with herbicides to which these crops are insensitive, first of all, glyphosate (N-(phosphonomethyl)glycine, $C_3H_8NO_5P$). This herbicide is present on the global market as an ingredient in the weed-killing chemical distributed under the trade name Roundup.

The toxic effect of glyphosate in plants is due to inhibition of 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS). This enzyme is involved in the shikimate biosynthetic pathway of aromatic compounds, precursors of tyrosine, tryptophan, and phenylalanine. Animals unlike plants have no shikimate pathway (no EPSPS accordingly). For this reason, glyphosate was long considered as the herbicide that is low toxic to animals and humans. Transgenic herbicide-resistant crops are insensitive to glyphosate because of the *EPSPS* gene of soil bacterium *Agrobacterium tumefaciens*. strain CP4 that was transferred into their genomes by genetic engineering techniques [28].

Glyphosate was first approved for use in 1974 in the United States. Currently, it is used to kill weeds in the fields for more than 100 agricultural crops in nearly 130 countries. The use of glyphosate in agriculture of the United States over the past 40 years has increased considerably: from 3180 tons in 1987 to 82 800 tons in 2007 [29]. In 2007, its proportion (by weight of active components) among all herbicides applied in the United States reached 40%. Similar dynamics of glyphosate use was also observed in Canada and several Latin American countries; it correlated in these countries with the expansion of areas allocated to so-called Roundup Ready Crops (soybean, cotton, canola, and maize) [30, 31]. Thus, the use of GM crops has led to the increase in application of pesticides rather than to its reduction. For example, in the United States in 1996 the average application rate of herbicides on soybean fields was 1.3 kg per hectare, whereas this quantity increased to 1.6 kg in 2006; in the case of cotton, the respective application rates were 2.1 and 3.0 kg/ha [32]. Another unexpected effect of the glyphosate usage has been unveiled just recently. It turned out that the destructive effect of glyphosate on vegetation causes soil erosion. As a result, the streams of surface water elute persistent pesticides (e.g., DDT) from the soil. Thus, these xenobiotics reappear as pollutants of ecosystems [33].

The question of the glyphosate toxicity to animals and humans is probably one of the most controversial issues in ecotoxicology. On March 20, 2015, the International Agency for Research on Cancer (IARC) announced the current outcome of these discussions by admitting that glyphosate is “probably carcinogenic to humans.”

The agency assigned this herbicide to the category 2A and admitted that glyphosate has a genotoxic effect and causes oxidative stress [34]. Glyphosate is usually applied not as a pure substance but in combination with other chemicals that are claimed to be “inert additives.” In most cases, the composition of such complex preparations is a commercial secret. The only exception is the herbicide Glyfos X-TRA; its label states that glyphosate content is 41% and the surfactant polyoxyethyleneamine (POEA) constitutes 14.5%. Chemical analyses of other commercial herbicides including Roundup showed a similar ratio of these ingredients [35]. The surfactants added in combination with glyphosate serve to facilitate permeation of the latter into plant cells. Comparative studies on the toxicity of Roundup and pure glyphosate to different species of aquatic animals have shown that the former was always more toxic than the latter (in some cases, the toxicity ratio was as high as 76). In turn, POEA is much more toxic than Roundup, not to mention the glyphosate [36]. Importantly, glyphosate in its pure form can exert toxic effects that are not evident after application of the composite product Roundup. For example, it was found that glyphosate, unlike Roundup, disrupted the maturation of oocytes in female crabs *Neohelice granulata* [37].

Another problem associated with glyphosate-resistant transgenic crops is the spreading of mutations conferring resistance to glyphosate to weed populations. In 2014, fourteen glyphosate-resistant weed species were recorded in the United States. In 2010, 5.6% of field area allocated for GM maize with a trait of glyphosate resistance was invaded by weeds resistant to glyphosate. Likewise, in the case of cultivating GM soybean with the same trait, the decrease in glyphosate efficacy was observed on 40% of field areas. The majority of these fields were located in the "Corn Belt" and the northern plains [38].

The possibility of "crossing" between glyphosate-resistant rapeseed (canola) and its wild relatives growing as weeds in agricultural fields represents a real danger. The potential of rapeseed hybridization with other species of subtribe Brassicinae is well studied. For example, in Canada, the glyphosate resistance trait was found in 1 to 17.5% of seeds of the weed *Brassica rapa* (bird rape) that grew on the edges of GM canola fields. Although the viability of most of these hybrids and their backcrosses is typically low, the resistance to glyphosate can improve the viability under appropriate conditions. For example, the selection pressure caused by the application of this herbicide greatly increases the survival rates, thus potentially promoting introgression of transgenes from GM-canola to related cruciferous species [39].

It should be noted that spreading of GM crops cannot be completely prevented even by the ban on cultivation. For example, in Canada, self-sown canola populations arise most likely as a result of accidental dispersal of seeds during crop harvesting and transportation, whereas in Japan, where GM canola is imported but not grown, self-sown plants were found repeatedly in port areas and along the roads where the seeds of this transgenic crop were transported to factories producing rapeseed oil (canola) [40]. Even the ban on import does not guarantee that the emergence of self-sown GM plant populations would be prevented. For instance, the cultivation of GM rapeseed is forbidden in the European Union, but five genetically engineered varieties of this crop are permitted for import as food and forage. On the other hand, Switzerland, not a member of the European Union, prohibited even the import of GM crops on its territory. Nevertheless, self-sown populations of GM rapeseed emerged even in this alpine republic. Their location in Basel has been correlated with the transit routes for transportation of the transgenic crop seeds: through the Rhine river port and the St. John railway station [41].

ECONOMIC–GEOGRAPHIC TRENDS IN DEVELOPMENT OF THE WORLD MARKET OF GM CROPS

The major part of economically developed countries has now revised their attitude to transgenic plants. Over the last 3 years, the growth of the area under GM crops was largely due to developing countries. The acreage of transgenic plants in these countries attained the level of developed countries in 2011 and surpassed it by more than 11 million hectares in 2014 (96.3 and 85.2 million hectares, respectively). According to statistics, in the United States ("historic homeland" of GM crops) GM crops are grown on 73.1 million hectares; in Canada, on 11.6 million hectares; and in Australia, on 0.5 million hectares. The remaining members of the "transgenic club" of developed countries, i.e., five European countries (Spain, Portugal, Czech Republic, Romania, and Slovakia) cultivate GM plants (Bt-maize MON 810 resistant to borer *Ostrinia nubilalis*) in symbolic amounts, in total on 143000 ha (148900 ha in 2013), which accounts for just 0.08% of the world field areas under GM crops [3, 42]. Thus, the contribution of the United States and Canada accounts for 99% of all transgenic plants grown in economically developed countries. Among the continents, the leading position in growing GM plants belongs to North America (85 million hectares, or 47%), followed by South America (73.19 million hectares, or 40%), Asia (19.6 million hectares, or 11%), Africa (3.3 million hectares, or 2%), and Australia (0.5 million hectares or 0.3%), with Europe at the end of the list (Table 2).

It is believed that GM plants are grown in countries comprising more than 60% of the world population (4 billion people), where the food problem is quite urgent. However, this is only a half-truth. The truth is that the most densely populated countries of Asia (China, India, and Pakistan) grow mainly GM cotton, a technical crop. Meanwhile, these countries accommodate 2.8 billion people, whereas 95% of GM plants intended as a food for humans and feed for livestock are grown in North and South America where only 14% of the world population lives (about 1 billion people). Some members of the "transgenic club" countries, whose territories comprise the centers of origin of cultivated plants, avoid growing GM lines of those species that are considered to be their "native" crops. For example, Mexico, European countries, and China refuse to grow GM-maize, GM-rapeseed (canola), and GM-soybean, respectively. This "opposition movement" was caused by the concern about the threat of "genetic pollution" of traditional varieties, as well as by the risks of emergence of herbicide-resistant weeds (in the case of rapeseed).

Although experimental plots are used for growing transgenic lines of almost all agricultural crops, the

Table 2. Global areas under GM crops in 2012–2014 [1–3, 42]

1	Countries	Area, million hectares			GM-crops
		2012	2013	2014	
1	United States	69.5	70.1	73.1	Maize, soybean, cotton, canola, sugar beet, alfalfa, papaya, large-fruit pumpkin
2	Brazil	36.6	40.3	42.2	Soybean, maize, cotton
3	Argentina	23.9	24.4	24.3	Soybean, maize, cotton
4	Canada	11.6	10.8	11.6	Canola, maize, soybean, sugar beet, tomato, sweet pepper
5	India	10.8	11.0	11.6	Cotton
6	China	4.0	4.2	3.9	Cotton, papaya, poplar, tomato, sweet pepper
7	Paraguay	3.4	3.6	3.9	Soybean, maize, cotton
8	South Africa	2.9	2.9	2.7	Maize, soybean, cotton
9	Pakistan	2.8	2.8	2.9	Cotton
10	Uruguay	1.4	1.5	1.6	Soybean, maize,
11	Bolivia	1.0	1.0	1.0	Soybean
12	Philippines	0.8	0.8	0.8	Maize
13	Australia	0.7	0.6	0.5	Cotton, canola
14	Burkina Faso	0.3	0.5	0.5	Cotton
15	Myanmar	0.3	0.3	0.3	Cotton
16	Mexico	0.2	0.1	0.2	Cotton, soybean
17	Chile	0.05	0.05	0.05	Maize, soybean, canola
18	Columbia	0.05	0.05	0.05	Cotton
19	Honduras	0.05	0.05	0.05	Maize
20	Sudan	0.05	0.05	0.10	Cotton
21	Cuba	0.05	0.05	0.05	Maize
22	Egypt	0.05	0	0	Maize
23	Costa Rica	0.05	0.05	0.05	Cotton, soybean
24	Bangladesh	0	0	0.00001	Eggplant
25	Spain	0.1	0.136962	0.131538	Maize
26	Portugal	0.05	0.05	0.08171	Maize
27	Czech Republic	0.05	0.0028	0.0028	Maize
28	Romania	0.05	0.000834	0.000834	Maize
29	Slovakia	0.05	0.0001	0.0001	Maize
Total (worldwide)		170.3	175.2	181.5	All crops

industrial production is still limited to only 11 crops: soybean, cotton, maize, canola (rapeseed), sugar beet, alfalfa, papaya, large-fruit pumpkin, tomato, sweet pepper, and eggplant. A prominent role in the global market belongs to only the first four crops (Table 1). The major part of presently grown GM crops has the traits of insecticidal or herbicide-resistant plants. The transgenic papaya is currently the only commercialized transgenic fruiting tree and the GM crop resistant to a phytopathogenic virus.

CONCLUSIONS

Year by year the global market of GM crops faces the increasing problems on the way to further expansion. These objective problems are based on several circumstances. One of them is the negative impact of insecticidal Bt-crops on beneficial and endangered invertebrate species, as well as the transecosystem flow of Bt-toxins. Other reasons include the allergenic properties of Bt-toxins to humans and the toxicity of glyphosate to humans and animals; the unrealistic claim of 10% profit against the background of the widespread resistance of weeds to glyphosate and of the insect pests to insecticidal Bt-plants; and the risks of "genetic pollution" of aboriginal varieties and the flow of herbicide resistant genes to weeds. The use of GM crops produced by transnational biotechnological corporations displaces the native crop varieties and makes some countries dependent on the procurement of the respective seed pools.

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