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# Are we destined to produce and consume GMO plants

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*Abstract: For many centuries farming was treated only as a source of food. Farmers aimed primarily at producing more and more food through using new technologies. Technologies of GMO plants production are conditioned by the need of increasing production while reducing use of pesticides. In the field of process innovations, the technologies using GM plants are the source of intensive emotions. On one hand their production is required by the times we live in, as there is a huge demand for soy products and biofuel on the market which cannot be supplied by existing technologies. One should also consider the fact that, for a significant group of farmers, technologies of the GM plants cultivation is the only option guaranteeing them sufficient income to earn their living. On the other hand, a significant part of consumers has a plethora of doubts about the GMO technologies. Therefore, it seems that in the nearest future people will be forced to apply this kind of innovation in agriculture.*

*Keywords: agri-food production technology, GMO, biofuel.*

# Introduction

The agriculture plays a significant role in economic processes which, however, tends to be underestimated.[1]. Generally, this kind of economic activity is considered lesser to the dynamically developing world of technology, whereas farm production and processes it initiates perform various essential functions. For many centuries farming was treated only as a means of food production. Consecutive generations of farmers aimed primarily at producing more and more food through use of new varieties of plants and animals. However, the necessity of producing an increasing amount of food forces the agricultural sector to search for new ways of development which would consider constantly changing market and consumers' needs.

The aim of this paper is to show the newest patterns in the development of agricultural sector and to consider its influence on modern agriculture and on the economic processes in natural environment. Production of GMO plants, which has been intensively introduced in the last years, was of particular interest to the authors. Development of technologies for cultivation of genetically modified plants is determined by necessity of increasing production while decreasing amount of used pesticides, however, demand is also increasing for food produced using natural methods, free from residual chemical byproducts.

# 1 Innovation of production in the environmental field

Innovations play a significant role in socio-economic development, and the term itself has been through a long way. Initially innovations were considered a form of creating demand, while nowadays they are rather viewed as a kind of answer to people's preferences. Such change in perception may result from the fact that it is not only technology that initiates the creation of an innovation. Observation of market, attitudes and social processes are equally important [5]. This also refers to broadly understood environment.

During the post-war period agriculture evolved mostly in the area of supply, which was caused by food shortages on European market. The intensification of production processes was especially important at that time in order to secure food security (figure 1). This was achieved by increasing the amount of pesticides used and intensive mineral fertilization. Parallelly to agricultural chemicalisation processes, research was undertaken and new, more efficient species of plants and livestock were introduced. These processes can be attributed to the first model of innovation, the science-driven innovation model. The distinctive feature of activities being undertaken at that time was limitation to strictly technical aspects

[1] Results of the paper are based on the research tasks of the Jean Monnet Networks project no. 564651-EPP-1-2015-1-SK- EPPJMO-NETWORK "Sustainable Land Management Network"

of process innovation. As a result, the market was saturated with consumption goods which led to increase in stock and difficulties in disposing of it in the EEC region. This generated high operational costs of the economic system. Therefore, agriculture supporting programs were developed, which limited production and were better correlated with consumers' needs. Thus, the market started gaining bigger influence on the offered goods, leading to emergence of market-driven innovations since 1970s. Market became the dominant factor in shaping economy and the producers focused more on meeting customers' expectations such as higher quality products. Based on the aforementioned, various research were conducted in order to develop production technologies allowing for products with lower chemical (fertilizers, pesticides) contamination.

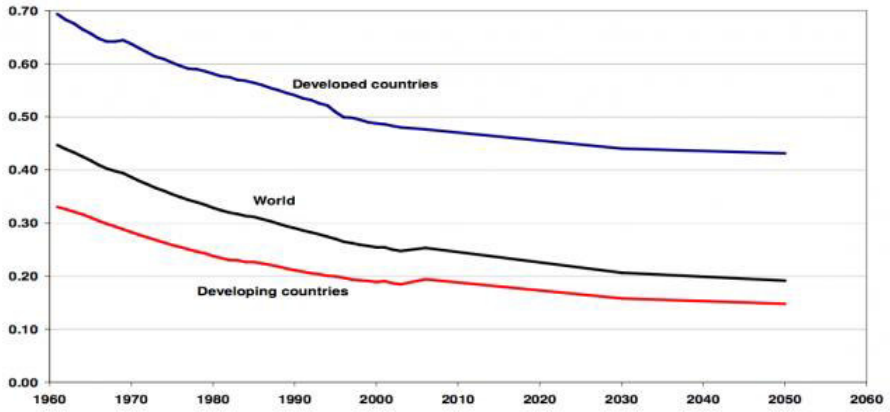


Figure 1
Arable land per capita (ha in use per person) (1961-2050)

Source: [3]

In consecutive decades, new conceptions of agricultural development appeared, focusing more on supplying the market with products that would meet customers' expectations in aspects of quality and security. Many of the agricultural producers (particularly in Europe) formed a new field of changes and adjustments associated with innovations in agricultural production technology.

Unfortunately, in most of the agricultural areas, the dominant type of production remained the supply-driven farming, also known as (intensive, industrialized, classic, etc.). Due to multitude of controversies around the use of huge amounts of pesticides, a new solution was proposed, offering a model of integrated farming (integrated, harmonious, balanced, etc.). Such production system was first proposed in 1993 by COST (*European Cooperation in Science and Technology*). The use of pesticides and fertilizers in this system is lower than in intensive farming, and the production process is based on crop rotation and adjusting farming to the environmental conditions. This was an attempt at combining efficiency and ecology

rules. In this case we can talk about a model of integrated innovation. This type of production assumes limitation of pesticides usage by 30-50% and consequential reduction of production by 3-7% [14].

The appearance of new information technologies also resulted in new tendencies in agricultural development in a form of high-tech agriculture. In this particular case, specialized information and navigation technologies and biotechnology are used, mostly in a form of genetic engineering. Unfortunately, it continues to resemble a form of conventional farming set on highly efficient production techniques based on intensive fertilization, significant amounts of pesticides and using microelectronics for steering the production processes. This particular model may also include precision farming, which uses GPS location system, as well as precise maps with information on soil fertility and other characteristics of the cultivated land [16].

In the recent years, agricultural farming and innovations therein follow various paths, creating new concepts of production and economical bonds between producers and consumers. These include: plant production for the energetic purposes, direct distribution channels of agricultural products, small processing industry in farms, creation of clusters in food production sector, etc. Moreover, we can observe various farming models with different approaches towards the issue of innovation.

# 2 Cultivating GM plants as an example of innovation

One of the most innovative areas in farming, inciting most controversies, is production of GM (*genetically modified)* plants[2]. The situation is striking as agricultural producers, industry and research institutions are all interested in development of those technologies and their application on a massive scale. Simultaneously, customers, pro-ecological organizations and many others (including governments of particular countries) are opposing the idea and they are either not interested in introducing those technologies into production or outright block them.

Very intensive development of genetic engineering in the recent decades made it most expansive technology in the history of agriculture. The first attempts of genetic modifications referred to tobacco and were tried out in 1980's, and the first product admitted to eating (1994) was tomato (*Flavr Savr*), which was characteristic for its'

[2] GM plants are organisms, genetic material of which has been changed in an unnatural way in order to get specific features: increased resistance to herbicides, insects or diseases, or in order to get features of higher quality (taste, smell, shape, color or durability in transport) – search [17].

longer storing period. Unfortunately, lack of customers' acceptation resulted in it being withdrawn from the market [11].

The GM production technology is eagerly accepted by farmers who can increase their profits through it. Other significant advantages are increasing food security and positive effects on power engineering, industry, etc. On the other hand, concerns arise over possible negative influence on consumers' health, as well as undesired changes in the environment. Despite the fact that, so far, no proofs of direct negative results of consuming such food have been found[3], the matter of safety creates emotions. Despite that, the GMO products keep appearing on consumers' tables and are used as a base of fodder for many farm animals. Soybean, maize, cotton and canola are most commonly planted GM plants around the world, but various research are being conducted and in the nearest future we can expect new GMO plants to be created.

In a modern diet (especially in a diet of the Americans) poultry, pork or eggs or milk, produced from animals which did not consume fodder without GM soy meal, are difficult to find. Soy meal has become an essential component of fodders used to increase production level, and therefore production efficiency. Approximately 95% of traded soy meal is made of GM plants. In 2014 82% of soy production area were the GM plants, and soy made up 50% of total GM production worldwide.

The area of GM plants production has been increasing dynamically since mid-1990's and achieved average yearly growth on the level of 30% (ca. 10 million hectares). Nonetheless, some sort of slowdown of the growth could be noticed in recent years, mainly in the developed countries. The cultivation of GM plants reached its peak in 2014, when 181,5 million hectares of farmlands were used for their production. In 2015, the area of GM crops dropped to the level of 179,7 million hectares (table 1). In recent years, the area of farmlands used for GM plants cultivation in the developed countries was stable and covered ca. 82 million hectares, while increasing dynamically in the developing countries to reach the level of 97,1 million hectares in 2015. The significance of this type of farming can be proved by the fact that GM plants cover around 13% of farmlands in total. The GM farming does not only concern the large farms. Every year, 18 million farmers (out of which 80% have a small farm) benefit from GM farming as it allows them to increase their production potential. This helps to limit areas of hunger and the constant excess is traded, thus improving the financial situation of the farmers [1].

[3] Some of the research indicates that herbicides and toxins *Bacillus thuringiensis* leftovers, which are not indifferent for people's health, pervade to food consumed by humans – search [11].

| Year | Hectares (milion) | Year | Hectares (milion) |
|---|---|---|---|
| 1996 | 1.7 | 2006 | 102.0 |
| 1997 | 11.0 | 2007 | 114.3 |
| 1998 | 27.8 | 2008 | 125.0 |
| 1999 | 39.9 | 2009 | 134.0 |
| 2000 | 44.2 | 2010 | 148.0 |
| 2001 | 52.6 | 2011 | 160.0 |
| 2002 | 58.7 | 2012 | 170.3 |
| 2003 | 67.7 | 2013 | 175.2 |
| 2004 | 81.0 | 2014 | 181.5 |
| 2005 | 90.0 | 2015 | 179.7 |
| | | Total | 1964.6 |

Table 1
Global area of GM crops in 1996-2015

Source: [9].

Consumers' resistance towards the GMO technologies used in agricultural production, and thus in food production, is clearly visible in Europe, unlike in the USA an in other countries. The USA is the global leader in producing GM plants and, at the same time, it leads in research for new GM plants, which are being produced on a massive scale. In 2015, the GMO farms covered around 71 million hectares (decrease by 2,2 million hectares in comparison to the preceding year) which made up for around 43% of total area of farms in the US. Maize, soybean, canola and cotton were mostly cultivated (figure 2). This was caused by the rise of biofuels market (ethanol fuel) and by the huge demand for high-protein soybean fodders. Only in the United States, the ethanol fuel production out of maize composes 40% of its production. The demand for GM soy resulted in around 95% grain trade and 85% soy meal trade being made up by GM plants.

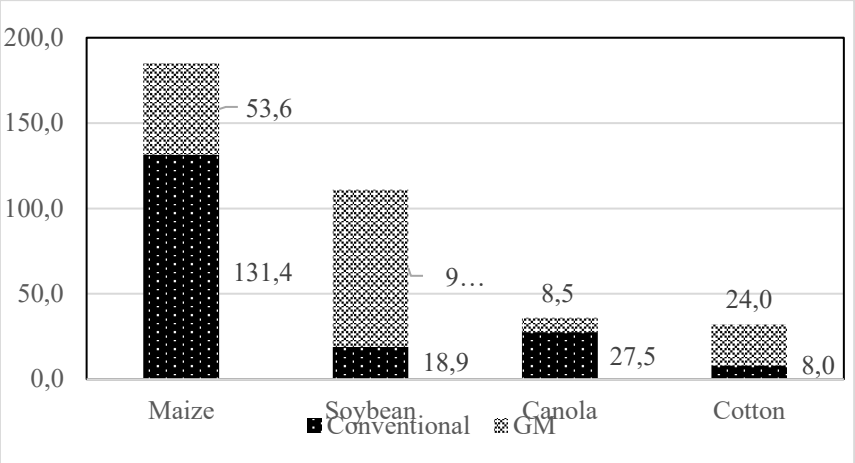


Figure 2
Principal crops – conventional and GM in 2015 in million hectares.
Source: Own elaboration based on [12].

Apart from plants the dominating in the GM production, such as: maize, soybean, cotton and canola, other plants, such as: sugar beet, potato, pumpkin, papaya, lucerne (alfalfa) etc. are being produced on an industrial scale (table 2). In years 1996-2013 the total growth of income generated by farming GM plants reached the level of approximately 58,4 billion USD in the USA, and approximately 133,5 billion USD worldwide [4].

Moods connected with producing GM plants on a massive scale significantly lengthened the process of creating legislation which would allow this type of production in selected countries. Although the first attempts of creating a uniformed law on possibility of starting GM plants production in EU date back to the early 1990's, they faced some serious obstacles as particular countries insisted that individual solutions are created, for example by creating GMO-free zones.

| Rank | Country | 2014 | 2015 | GM crops |
|---|---|---|---|---|
| | | (million hectares) | | |
| 1 | USA | 73.1 | 70.9 | maize, soybean, cotton, canola, |
| 2 | Brazil | 42.2 | 44.2 | soybean, maize, cotton |
| 3 | Argentina | 24.3 | 24.5 | soybean, maize, cotton |
| 4 | India | 11.6 | 11.6 | cotton |
| 5 | Canada | 11.6 | 11.0 | canola, maize, soybean, sugar beet |
| 6 | China | 3.9 | 3.7 | cotton, papaya, poplar, tomato, |
| 7 | Paraguay | 3.9 | 3.6 | soybean, maize, cotton |
| 8 | Pakistan | 2.9 | 2.9 | cotton |
| 9 | South Africa | 2.7 | 2.3 | maize, soybean, cotton |
| 10 | Uruguay | 1.6 | 1.4 | soybean, maize |
| 11 | Bolivia | 1.0 | 1.1 | soybean |
| 12 | Philippines | 0.8 | 0.7 | maize |
| 13 | Australia | 0.5 | 0.7 | cotton, canola |
| 14 | Burkina Faso | 0.5 | 0.4 | cotton |
| 15 | Myanmar | 0.3 | 0.3 | cotton |
| 16 | Mexico | 0.2 | 0.1 | cotton, soybean |
| 17 | Spain | 0.1 | 0.1 | maize |
| 18 | Colombia | 0.1 | 0.1 | cotton, maize |
| 19 | Sudan | 0.1 | 0.1 | cotton |
| 20 | Honduras | <0.05 | <0.05 | maize |
| 21 | Chile | <0.05 | <0.05 | maize, soybean, canola |
| 22 | Portugal | <0.05 | <0.05 | maize |
| 23 | Cuba | <0.05 | <0.05 | maize |
| 24 | Czech | <0.05 | <0.05 | maize |
| 25 | Romania | <0.05 | <0.05 | maize |
| 26 | Slovakia | <0.05 | <0.05 | maize |
| 27 | Costa Rica | <0.05 | <0.05 | cotton, soybean |
| 28 | Bangladesh | <0.05 | <0.05 | brinjal/eggplant |
| | Total | 181.5 | 179.7 | |

Table 2.
Global area of GM crops in 2014 and 2015
Source: [8].

As a result of mass objections and relatively radical laws limiting trade of GM plants in EU, by the end of 2015 maize MON 810 (created by the Monsanto concern and resistant to *Lepidoptera* insects) was the only GM plant admitted to production. Before 2013, the permission also covered the *Amflora* potatoes (created by the

BASF concern; they were the source of amylopectin starch, useful in papermaking industry and textile industry). Despite that, law was not as strict towards GMO products included in fodders and food and therefore these were admitted to import and processing. The admission referred to 32 types of maize, 12 types of soybean, 10 types of cotton, 4 types of canola and 1 type of sugar beet [6].

An approval of the regulation by the Council of the EU on March 2, 2015, according to which every GM plant which was intended to be cultivated in EU would have to go through two-stage verification, was the final touch of the long-lasting legislation process. Nevertheless, every member country was able to forbid cultivation of a GM plant by indicating one of the reasons: environment protection reasons, social or cultural reasons. Moreover, until October 3, 2015 particular members of the EU were allowed to inform European Commission about intention of forbidding GM farming (opt-out policy). 19 countries of the EU declared such intention: Austria, Belgium (the region of Wallonia), Bulgaria, Croatia, Cyprus, Denmark, France, Greece, the Netherlands, Lithuania, Luxemburg, Latvia, Malta, Germany, Poland, Slovenia, Hungary and Italy. In the Great Britain, nearly 100% of the area of Ireland and Wales, as well as around 50% of farm lands in England were under the prohibition of GMO production.

Poland is one of the biggest opponents of using GM plants and Polish law is constructed in a way that forbids cultivation and selling the GM products. In recent years, every action leads towards limiting possibilities of cultivating GM plants, and only the moratorium, which was the result of interest groups pressures (initially until January 2017), gave the possibility of using such plants as components of fodder[4]. Noticeably, activities towards finding an alternative fodder, which could be produced by the Polish producers, did not provide the desired outcome [15]. As a result, Polish government decided to extend the moratorium for launching GM fodders by 2 years (initially, the proposal was for 4-year extension) – until January 1, 2019 [13].

Moreover, the government bent down under the pressure of the European Union in terms of allowing GM farming in Poland. Such crops can be cultivated only in the selected areas and the permission has to be given by the Minister of Environment after receiving positive feedback for the proposition from the Minister of Agriculture and from proper local authorities. Additionally, a farmer potentially interested in GM production will have to receive declarations from all landowners of lands within the distance of 3 km from the area on which they plan to cultivate GM plants, stating that they approve of the cultivation. This should protect apiary owners in the area. Putting so many obstacles on the way may result in using the law for successful banning GM farming [10].

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[4] Unfortunately in this case Poland has to respect the decision of the European Committee which, by qualified majority of votes, will be allowed to permit the GMO production (decision will be valid 10 years). On the basis of such decision, products permitted for trade in one country will be allowed into trade in the entire EU.

# 3 The significance of biotechnology and GM fodder for livestock production

The technological changes that took place in livestock production in recent years, were the result of internal and external agents. Firstly, agricultural producers gave up on the expensive fodder and the searched for cheaper production methods. Secondly, the BSE crisis resulted in a ban on using meat-and-bone meal for feeding livestock. Contrary, as the effect of the genetics' development, new breeds of animals became more demanding in terms of fodder composition, though this further results in producing more low-fat meat. In this case, consumers' influence on innovation process can be seen clearly, as they created demand for meat with lower fat content, which was reflected in research and development (R&D) of new species of pigs and cattle. Unfortunately, not all of the consumers liked the idea and part of them are still sentimental about "the good old flavours". This is a result of the fact that products with higher fat content (which carries the flavour) from the past, were more probable to be remembered as extremely tasty in the consumers' minds.

Contemporary rational feeding of the livestock requires fodder to consist of proper amount of valuable protein, energy value, minerals and vitamins. As a result of dismissing potatoes for fattening pigs, soy meal has become the most important ingredient of fodders. Unfortunately, fodders produced within Poland contains s only 30% protein coming from leguminous plants, canola or fish meal. In this situation, any possible withdrawal from using imported fodder which would contain GMO would mean significant losses for the farmers or need for significant changes in farming towards cultivating high-protein plants [6].

In case of feeding poultry, the situation looks very similar as in case of fodder for pigs and cattle made with GM plants. Currently, commercially crossed poultry requires balanced high-protein fodder, which cannot be obtained from natural grain. Noteworthy, using high-quality fodder, as well as genetic research, contributed to shortening the broilers production cycle to 5-6 weeks. As a result, in case of poultry breeding, producers are forced to use fodders based on post-extraction soy meal[5]. Otherwise, poultry producers would be forced to stop production or to switch to less efficient technologies. At the same time, Poland is the leader of poultry and eggs production in Europe. Polish producers account for approximately 40% of meat and 40% of chicken eggs in the EU.

In case of cattle breeding, high-protein fodders made of soybean are an irreplaceable source of energy. New high-efficiency cow breeds require balanced feeding and, basically, only the fodder protein found in post-extraction soy meal can provide sufficient health and productiveness of the animals. In case of cattle breeding, any possible alimentary errors can also lead to metabolic disorder, which might result

[5] Statement of prof. A Rutkowski from UP in Poznań during a session of the Commission of Agriculture and Countryside Development on 27th January, 2016 [15].

in drop of economic efficiency, as well as in higher emission of nitrogen to the environment [7].

# 4 Biofuel production

The basic material used for 1st generation liquid biofuels are cereals, sugar cane and plant oils, which back in 20th century were used mostly for food and fodder production, and nowadays pose a serious competition. According to the data from the World Bank's report from 2008, as an effect of increased demand for biofuel, especially in Europe and in the US, food prices rose. As F. O. Licht's data indicate, in 2000-2014 bioethanol production rose over threefold, i.e. from the level of around 29 billion to 94 billion litres; and the biodiesel production rose 26 times to the level of 26 million tons (figure 3).

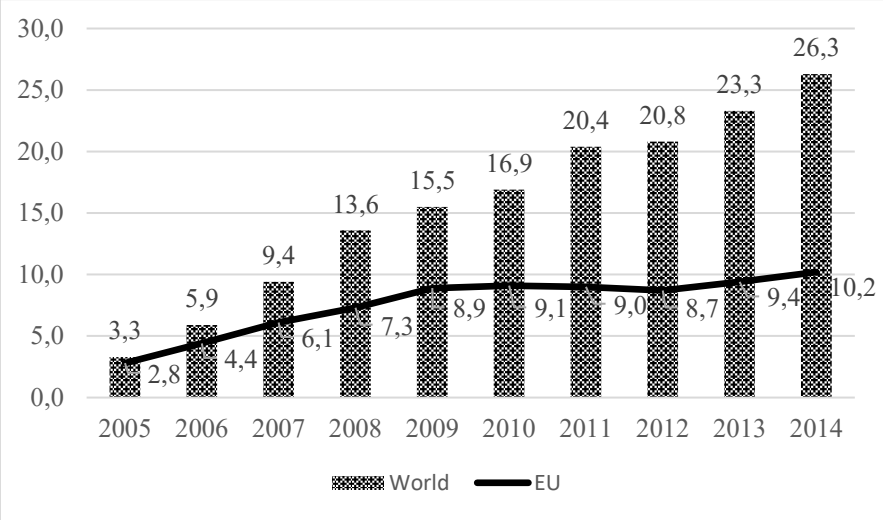


Figure 3.
Biodiesel production in million tons

Source: Own elaboration based on [2]

Despite the systematic increase in liquid biofuel production, their use is still relatively low in comparison to global liquid fuel use in transport. In the EU and the USA biofuels account for approximately 3-5% of supply. One of the main reasons of such distribution on the market is that biofuel production is significantly more expensive than that of mineral fuel. The high cost of biofuel production is mainly determined by costs of obtaining the material, as it makes up for 55-70% of its cost. One of the main directions chosen by various countries is to use biofuel universally, as they allow achieving set social goals such as environmental protection or

increasing energetic safety for instance. These goals might be achieved by introducing fiscal-administrative regulations in the biofuel market. Commonly accepted and used tool is the requirement of mixing biofuels with mineral fuels, which is aimed at guaranteeing market for biofuels. Therefore, increasing the biofuel production has become one of the most important factors causing the increase of global production and trade of agricultural resources (cereals, oilseeds and plant oils). Although this contributed to increasing farmers' income, higher demand also led to increases in food prices and had negative impact on food security, especially among people with low income in the developing countries. Tendencies to limit the support for biofuel (produced with 1st generation agricultural products) production, for the purpose of increasing the use of biofuels of further generations made out of non-alimentary minerals, are seen on global scale. The still-increasing competition for agricultural raw materials between alimentary and biofuel sectors can be expected to maintain high level of the prices on the market [2].

# Summary

Since the end of 20th century, innovation processes happening in the area of agriculture can be clearly noticed. These processes lead towards introducing more and more intensive production technologies such as: cultivating new types of plants and breeding more efficient livestock. This way, a satisfactory level of production has been achieved, nonetheless bringing some doubts about safety of the direct consumers. The leftovers of the pesticides and fertilizers became a threat for people's health. Moreover, such intensive farm production is harmful for the surrounding environment.

In the field of process innovations, the technologies using GM (Genetically Modified) plants are the source of intensive emotions. Their production is required by the current circumstances, as huge demand for soy meal on the market and the demand for biofuel cannot be supplied by existing technologies. On the other hand, a significant part of consumers has a multitude of doubts about the GMO technologies. Relatively short period of their production, as well as lack of deep research, disallow unequivocal claims on their harmlessness for consumers. The fact that, for a significant group of farmers, cultivating the GM plants is the only option guaranteeing them sufficient income to earn their living, should also be considered. Therefore, in the nearest future, people will seemingly be forced to use this kind of innovation in agriculture.

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