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Biotechnology: Two Decades of Experimentation with Genetically Modified Foods

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Abstract

Background and Objective: Over the recent years, genetically modified food in varieties of corn, soybeans, canola and cotton have been introduced to the global market. This study reviews the health and nutritional value of genetically modified foods in the past two decades.

Results and Conclusions: Contrary to the present biotechnological claims, transgenic products did not prove to be so flawless, and actually failed to maintain social satisfaction. Genetically modified foods could not gain an increase in the yield potential. Planting natural products and genetically modified products in parallel lines will absolutely result in genetic infection from the side of genetically modified foods. One of the major anxieties of the anti- genetically modified foods activism is the claim that genetically modified crops would alter the consumable parts of the plant quality and safety. Genetically modified foods have shown to have inadequate efficiency and potential adverse effects in both fields of health and biodiversity. This review has presented studies of genetically modified foods performances in the past two decades, and concludes that the wide application and the over generalization of genetically modified foods are not fundamentally recommended.

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1. Introduction

Transgenic crops are often referred to the products being genetically modified through a process known as genetic engineering. Transgenic plants bear a close resemblance to their natural counterparts. However, via genetic modification, they generally excel over their non-genetic modify-cation counterparts in one or more specific properties [1,2]. Transgenic products have so far been globally produced through various plant trans-ormations. Some typical examples of trans-genic crops are soy beans, rice, maize, barley, cotton, potato, canola, sweet potato, tomato, squash, sugar beet, papaya, apple, mango, banana, pineapple and coconut [2]. Transgenic techniques have been widely accepted worldwide as the fastest growing technology during the history of agriculture. However, genetically modified (GM) products have been born via some substantially and technically distinguished methods from those used in plants conventional fecundation, and have failed to offer safety and health in consumption to the world population [2-3]. European Union's legislation defines GM foods as "In GMOs (Genetically Modified Organisms), the genetic material has been transformed in such a way that won't ever occur naturally during traditional crop breeding or fertilization [1-3].

Plant genetic engineering methodology ultimately aims to transfer one or a few genes to a certain crop plant and, if conducted satisfactorily, a novel property would be granted to the targeted plant. This recent property is not recognized among the species sharing a common ancestor. Samples of transgenic plants use, which are distinguished by a specific trait as resistance to a certain plant pest, plant diseases or capability to withstand dry condition, are nowadays widely practiced in modern agriculture. Acceleration in world population growth and an augmented demand for foodstuff during a recent couple of decades have led to the implementation of certain agricultural genetic technologies and crop production approaches. The result was a bio-revolution undergoing a development from conventional to modern farming methods [4-6].

In the current modern agriculture, issues such as plant breeding and resistance to diseases, crop yielding and the ability to withstand against environmental adversities such as drought and salt stresses have widely been the center of notice by the assistance of genetic engineering [4-5]. However, the concept of genetic transformation will itself prompt a huge amount of complications affecting food safety, and will turn into a real threat to the social health. This can potentially lead to the initiation of certain chronically lethal diseases, which are potentially life threatening for the mankind [4,5].

Evidence has shown that transgenic crops contain some distinctive contents from a non-transgenic type even though if both are planted under the same circumstances, holding a single time and place [4-6]. This confirms the idea that the recent alterations are not due to the environmental circumstances, rather they are induced by some genetic transformations [4-8]. Alterations in the nutritional value can be discomforting for two reasons: First, these products that reduce or enhance a certain nutrient bioavailability can influence directly on the overall health condition of the people or the animals who are the consumers. Second, this could reflect that genetic transformation has implanted several alterations in the biochemical pathways of the cell [5-8]. So this clue could be extracted that there might still exist some more unpredictable alterations that are not recognized yet, such as creating toxins and potential allergens, which might be assumed of adequate significance in both humans' and animals' general health [4-7]. Transgenic crops have proved to be a real threat to human health [1-10]. The reason for that is the rise of certain mutations along the genetic transformation process potential of either gene modification or affecting the bioactivity and cellular structure. These kinds of modifications could result in some other transformations occurring in the cell composition that are not predominantly welcome, as they generally leave their destructive impact on the human health. The current methods widely used by the genetic engineers together with the tissue cultivating procedures are believed to be inaccurate and potentially mutagenic. They may basically lead to some unpredictable alterations in the genetic material DNA, proteins and biochemical processing of the transgenic products. These previously mentioned unpredictable changes may occur as toxicity, development of allergy, changes in the nutritional values of transgenic products, nutrient reduction, paving the way for chronic diseases and causing harm to the tissues and body organs. Thus due to the induced health hazards to humans imposed by these products, they are not fundamentally recommended [8-10].

The health claims existing on transgenic products are mostly inaccurate, and manufacturing of these products would not increase the crop yields [8-12]. In fact, studies have shown that genetically modified plants not only failed to decrease pesticides application but also they have caused an increase in pesticides usage, disturb the farmers by the over growth of tall weeds resistant to herbicides, deteriorate the quality of soil, worsen the marketing, prompt adversely mixed economic effects in the market, chemically damage the composition of the soil, destruct the ecosystem, and finally, reduce biodiversity [10-15]. Though GMOs have proved to be unable to solve the global hunger catastrophe, they could distract the international attention from the major causes of the world hunger. Some of the primary causes of the world hunger are poverty, lack of food access and small scale agricultural land in the hands of farmers. These are all considered as the side effects stemming from the manufacturing of transgenic products [11-17].

This study reviews the literature pertaining to GMOs and how they have so far failed biotechnology to manufacture healthy foods and environmentally-friendly agricultural products.

2. Method and search strategy

To conduct the research, the following keywords were used: "Herbicide", "Agricultural pesticides", "Biodiversity and economy", "Gene transfer", " Safety", "Changes in gene expression" , "Public concern", "Agricultural biotechnology", "Genetic engineeering", and "Genetically modified products". Data sources: Google scholar, Science Direct, Pub-Med, EMBASE, and Cochrane Library were comp-rehensively searched for papers that addressed the "Genetic modification of food" since 1985 till 2015. The whole search basically included the key words, and all the studies targeting the current subject were taken into consideration.

3. Results

Transgenic products undergoing biotechnological manufacture and the success rate of their acceptance were measured through different aspects.

3.1. GMO yield

There are some reports in which GM crops have not resulted in yield increases [18-20]. Instead, the progressive increases in yield of major agricultural products over the last decade have been predominantly observed where the traditional fusion techniques have been applied [18,19]. The augmented yield is absolutely due to the com-plicated genetic properties that involve the expression of several genes simultaneously. Com-parative studies between agricultural products of the Western Europe and the US indicates that non-GMO varieties have got higher yields and require less herbicide as compared to their genetically transformed counterparts [18-20]. Contrary to the claims so far made, the statistics show that some countries that have significant achievements in the production of GM crops are basically falling behind the countries with higher rates of natural products. Academic studies indicate that GM soybeans would record lower yield as compared to their non-GM counterparts [18,19]. In such controlled studies, 50% of the fall in the GM soybean production is due to the gene expression disorder induced by the genetic modification procedures comparing to the non-GM varieties [19].

Moreover farm experimentations on some of the corn production reveal that complete growth of GM crops requires time extension, and has had 12% decline in production rate when compared to non-GM products [20].

In 2002, the US Department of Agriculture announced that GM foods that currently exist would not seem to gain any production raise. In fact they would go for a production decline as well [21]. In 2014, the US Department of Agriculture reported that "No document so far exists to indicate the greater GM crops' potential regarding the yield increase" [22]; rather those resistant to the herbicides and resistant against pests have somehow proved less efficient and vulnerable. Of course, this is not as eccentric as it may seem because manufacturing of GM crops was not ultimately targeting for the increase of production rate and efficiency. Rather, the main objective has been to genetically engineer certain plants in order to develop the potency of herbicide resistance in them so that these plants could endure the pests and insects more easily. As mentioned above, crop production is closely dependent on the genetic template of the plant, which is rather complicated and involves several genes. Issues as cultivated land and cultivation methods are of significant importance. Increasing the production rate is not achievable by simply modifying one or a few genes, which is frequently done by genetic engineering techniques. In a comparative study performed in 2013 on the productivity rate between the EU and the US, the results argue that EU has got higher productivity per hectare and applies minimum chemicals within the farming process, while the US is lagging behind the Europe due to greater use of gene manipulation technology for increasing prod-uctivity and disease resistance [23]. The important point, which is worth considering here is that if genetic transformation fails to increase agricultural productivity in the developed countries with perfect irrigation conditions and sufficient governmental subsidies in the agriculture sector, how can we expect an increase in the agricultural production rate in the under-developed countries facing with huge amounts of difficulties in the field of agriculture, and where the majority of people are engaged in cultivating a single product [22-28].

3.2. A number of agricultural herbicides used for GMO protection

It has widely been claimed that using GM crops will certainly lead to the lower amount of insecticide and herbicide application. This would not seem to be a rightful claim and, in fact, products resistant to these pesticides prompt a significant increase in the application of herbicides. The majority of these products have been designed in such a way that their breeding depends on widespread glyphosate use. An estimation of 183,000 tones equal to 7% increase in herbicide and pesticide use has been so far recorded in the US, comparing to a similar planting area if allocated to non-GM crop types. Unfortunately due to the widespread application of herbicides and pesticides, farmers are facing a huge problem and that is the growing rate of weed and insect resistance to herbicides and pesticides. Wide application of these chemicals will not ever result in a sustainable agriculture in the long term. Instead, it would endanger the environment with highly resistant weeds and insects whose fighting strategies might be so critical and biologically out of control [28-31]. A paper focusing on the impact of GM crops on the herbicides and pesticides application rate within a period of 16 years was published in 2012 [32]. This study reported that soybeans resistant to glyphosate contribute to the 70% development of the herbicide application rate. This is not surprising as the manufacturers of GM crops are exactly those who are involved in the manufacturing of pesticides and herbicides. Clearly, it would be a pure profit for them to produce some types of the seeds that are closely dependent to those killers [33].

There have been similar reports on the increasing rate of herbicides use coming from several parts of the world like the south US that are widely applying GM foods throughout the region. In countries like Argentina [34] and Brazil, the percenttage of increase in herbicides per hectare has been also reported [35]. Unfortunately, with the over-growth of the weeds resistant to glyphosate, farmers are forced to apply a greater amount of herbicides or switch to some other varieties with higher efficiencies; this will consequently lead to a serious hazard for the human general health and the environment. According to some reports from

Canada, GM canola seeds have substantially turned into a type of weed spreading throughout all the farmlands of soybean and corn [36].

In addition to the landmark increase of herbicides use in growing GM crops and the significant threat it imposes to the environment, the other major concern deals with the amount of induced resistance to these killers that is expressed in every single GM plant cell, and will extend a lifelong. This toxicity remains as far as if any part of the plant is consumed by the beneficial insects; it will lead to environmental disasters and leave its unpleasant effects on the ecosystem and biodiversity, eradicating, as a result, the natural enemies of the insects as well. An article published in 2011 announced that toxin resistant worms were recognized in some US states as Iowa and Illinois [32,37]. In India and China, GM cotton seeds production resulted in toxin resistance, and caused the old insects to be replaced by some other types [38-39]. Another study on glyphosate indicated that this toxin, after being scattered over the GM crops, accumulates within the plant tissues. Then the toxin is released to the soil through the roots, inducing the growth of certain fungi, named Fusarium, which would infect the plant with some sort of infections. The major concern about this fungus is that it could produce a type of toxin able to penetrate into the human and animal food chain, and may leave acertain disastrous impact on the reproductive system [39-42].

3.3. The impact of GM seeds on biodiversity and economy

One of the well-known studies so far conducted on the GM crops and biodiversity rate is of Britain's, done in the late 90s. In this article, the impact of four GM products upon the biospecies existing in an agricultural land with a definite size was studied and compared with the non-GM varieties. The results showed that the herbicide resistant products caused a statistically significant decrease in native weeds and their seeds, which could result in the biodiversity fall of the wild life [43,44].

Regarding the economic view of GM crops, as for their close dependence on some various and complicated agents, controlled studies with documented data are rarely present. Some of the major factors affecting the GM crops economy are proper selection of the product for the indigenous and environmental status, easy access to improved water sources, climate conditions, seed costs, pres-ence of vermin and the spread of disease, costs of insect-control systems, subsidies, governmental and private sector allowances, and product marketing. In 2006, European Commission studies on the economic impact of GM soybeans resistant to herbicides indicated that there had been a negative impact on the farmers' welfare in the US. But in Argentina because of the lower prices of the government subsidized GM crops, the farmers' income tended to show a certain increase [45]. It has also been mentioned in the same report that GM cotton crops in China brought the farmers an income increase. However this increase stemmed from the lower herbicide costs in China. An Indian study based on the GM cotton crop production showed that even though there happened to be a temporary increase in the Indian farmers' outcome, studying a 5-year-duration of using this specific variety of cotton brought the farmers so much harm and damage as far as leading some of the GM cotton planters to commit suicide during 2011-2012 [46].

One of the negative agents in the GM crop economy is that their manufacturing is exclusively in the hands of a few companies that have the authority to subjectively stabilize the crop prices. In 2008 in US, 85% of the patents on corn output and 70% of GM crops excluding corn have been allocated to 3 specific companies; however, these three companies are conducting internationally close negotiation for the price stabilization of crops. This was a so crucial concern that the US criminal justice system initiated a vast inquiry regarding the exclusive activities of one of the engaged companies as the greatest GMO seed producing agency during the years 2009 and 2010 [33,47-49].

3.4. The possibility of gene transfer from GMOs to non-GMOs

Planting natural products and GM products in parallel lines will absolutely result in genetic infection from the side of GMOs, and lots of documents from countries like China, Germany, Sweden, New Zealand and Canada are authenticating this fact. The results indicate that, in near future, the farmers would be less authorized to choose their agricultural practices and the type of agricultural products. Unfortunately, GMOs are not specifically selected. Rather since they are living organisms, they will find their way and start over growing. Interestingly, in those countries that criminal justice system contributes for the standard purity of agricultural products, the GMO producing agencies are fated to experience extensive financial loss due to the overspreading of the seeds to adjacent agricultural lands [50-54].

Horizontal gene transfer among unrelated biological types takes place via a mechanism other than reproduction, and the scientists have already warned that modified genes may simply escape from genetically engineered products and transfer to other organisms horizontally. Although horizontal gene transfer between two plants or from a plant to an animal might rarely occur; however, DNA (the genetic material) uptake by the bacteria in an environment or through the digestive system is probable. Some reports indicate that DNA uptake by the bacteria existing in the digestive system of GM soybean consumers is likely to take place. Moreover, the soil bacteria have the capability to transfer

the DNA probably existing in soil to their own genome [55-57]. Although gene transfer probability to pathogenic bacteria and viruses seems to be low, regarding the global abundance and overspread of GM products, this transfer is expected to take place in the near future. This scientific fact exhibits that the biosafety issue, concerning the GM crops, and their transfer to other organisms and carrying all the properties that might be a hazard to the human health, has to be entirely taken into consideration. There are several concerns on the potency of herbicide resistant plants for creating a certain new inconveniences regarding the existence of weeds. This means that they may be either transformed to weeds or cause various difficulties due to the escape of the herbicide resistant transferred genes to the other members of the plant family or to the wild species. Gene flow to the native plant population capable of cross-reacting with the herbicide resistant crops may lead to certain unpleasant agricultural or environmental consequences [58-60].

One of the major anxieties of the anti-GMO activism is the claim that GM crops would alter the quality and safety of consumable parts of the plant. This might occur through toxicity of the protein produced by the transferred gene, toxic metabolites derived from the transferred gene coded enzyme, transferred gene induced pleiotropy, unmodified gene expression alteration by the transferred gene position in the genome or various indirectly affecting occurrences. To approve commercial supply of GMOs, these crops are more accurately being measured than the conventional plants via analytical, nutritional and toxicological techniques [59-60]. Another concern is the impact of applied herbicides among the resistant crops upon the non-target organisms. Since glyphosate acts as an herbicide, wind dispersal of glyphosate towards the non-target plants could also be detrimental [61]. Intermixture and conflation of GM and non-GM crops due to the natural pollination and unwanted transfer of these genes to the adjacent non-target plants are other irritating concerns. It is believed that when planting a GM seed, after the harvest, the stem of the GM plant remains in the soil or is used as the livestock feed, so that it could leave an impact on the soil microorganisms, and the mentioned gene could influence on the soil ecosystem and the living insects and organisms there as the second cycle. It may also influence on the birds feeding on these insects. Another matter to worry is the human nutrition and the probability of the new allergies outbreak induced by the long term use of GMOs. To identify these probable unknown allergies in humans, long term expert assessment needs to be done by the governmental sector. In many cases, gene transfer and the site of gene insertion in the host cell genome are not clear. So a new gene is inserted into the host cell's genome in a randomized site, and interrupts the interrelationship between the genes of that specific location. This process may affect unpleasantly on the living organisms due to the cumulative effects and interaction of genes with one another or might lead to the construction of some environmentally destructive outputs [62-67].

4. Conclusion

Contrary to the present biotechnological claims, transgenic products did not prove to be so flawless, and actually failed to maintain social satisfaction. GMOs could not gain an increase in the yield potential. Nevertheless, the last century yield potential increase of the primary agricultural products has substantially prompted by the natural conventional fusion techniques. The yield potential increase pertains to the complicated genetic properties that could involve several genes. Non-GMOs have got higher yield potential, and depend on less herbicide use comparing to most of GMOs. However, no document indicating that GMOs are having higher yield potential increase has yet been released. Contrary to the present claims arguing that GMOs will surely lead to the less application of herbicides and insecticides; in fact, resistant products will cause a drastic increase in herbicides' application. For this reason, farmers are presently dealing with a huge problem, i.e. the resistance of weeds and pests to these killers. Herbicide-resistant crops will statistically reduce the rate and spread of certain natural weeds and natural weed crops, and will contribute to the reduction of the wild life diversity. Planting natural and GM crops in parallel lines will definitely lead to the genetic infection from the side of GMOs. Horizontal gene transfer between unrelated biotypes takes place via mechanisms other than reproduction, and the researchers have already warned that modified genes may simply escape from certain products and be transferred to other organisms horizontally. Gene flow to the native plant population, capable of cross-reacting with the herbicide resistant crops, may lead to certain unpleasant agricultural or environmental consequences.

In the past two decades, GMOs have shown to have inadequate efficiency and potential adverse effects in both fields of health and biodiversity. Moreover, GMOs have failed to fulfill human needs, and can prompt certain hazards for the environment and economy via the process of gene transfer. Comparing to their non-GM counterparts, failure in less application of pesticides and also less yield potential of these products have reflected them as entirely worthless stuff, imposing a lot of inconveniences and dissatisfaction for the farmers, causing huge damage to the soil, destruction of the ecosystem, and biodiversity reduction. In this article, we reviewed the literature related to GMO performances in the past two decades, and it is concluded that the wide application and the over-generalization of GMOs are not fundamentally recommended.

5. Conflict of interest

The authors declare no conflict of interests, and that this study did not receive any financial support.

References

1. European Parliament and Council. Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms and repealing Council Directive 90/220/EEC. Off J Eur Communities. 2001:1–38doi: http://www.wipo.int/wipol-ex/en/details.jsp.10335.
2. Craddock N. Flies in the soup-European GM labeling legislation. Nat Biotechnol. 2004; 22(4): 383-384. doi: 10.1038/nbt0404-383.
3. Marillonnet S, Klimyuk V, Gleba Y. Encoding technical information in GM organisms. Nat Biotechnol. 2003; 21(3): 224-226. doi: 10.1038/nbt-0303-224.
4. Weis P. Genetic modification. Europe prepares for arrival of GM foods. Science. 2002; 298(5601): 2109-2110. doi: 10.1126/science.298.5601.2109a.
5. Hino A. Safety assessment and public concerns for genetically modified food products: the Japanese experience. Toxicol Pathol. 2002; 30(1): 126-128. doi: 10.1080/01926230252824815.
6. Then C, Bauer-Panskus A. European Food Safety Authority: A playing field for the biotech industry. Testbiotech; 2010. Available at: http://www.testbiotech.de/en/node/431.
7. Bennett, R., Phipps, R., Strange, A., and Grey, P. Environmental and human health impacts of growing genetically modified herbicide-tolerant sugar beet: A life-cycle assessment. Plant Biotechnol J. 2004; 2: 273-278. doi: 10.1111/j.1467-7652.2004.00076.x.
8. Delaney B. Strategies to evaluate the safety of bioengineered foods. Int J Toxicol. 2007: 26(5):389-99. doi: 10.1080/10915810701582855.
9. Selgrade MK, Kimber I, Goldman L, Germolec DR. Assessment of allergenic potential of genetically modified foods: An agenda for future research. Environ Health Perspect. 2003; 111(8): 1140-1. doi: 10.1289/ehp.5815.
10. Devos Y, Reheul D, De Schrijver A. The co-existence between transgenic and nontransgenic maize in the European Union: A focus on pollen flow and cross-fertilization. Environ Biosafety Res. 2005; 4(2): 71-87. doi: 10.1051/ebr:2005013.
11. Quist D, Chapela IH. Transgenic DNA introgressed into traditional maize landraces in Oaxaca, Mexico. Nature. 2001; 414:541-543. doi: 10.1038/35107068.
12. Malatesta M, Biggiogera M, Manuali E, Rocchi MBL, Baldelli B, Gazzanelli G. Fine structural analyses of pancreatic acinar cell nuclei from mice fed on genetically modified soybean. Eur J Histochem. 2003; 47:385–388. doi: 10.4081/851.
13. Rosi-Marshall EJ, Tank JL, Royer TV, Whiles M. R., Evans White M., Chambers C., Stephen M. L. Toxins in transgenic crop byproducts may affect headwater stream ecosystems. Proc Natl Acad Sci USA. 2007; 104:16204-8. doi: 10.1073/pnas.0707177104.
14. Malatesta M, Caporaloni C, Gavaudan S., Rocchi M. B., Serafini S., Tiberi C., Gazzanelli G. Ultrastructural morphometrical and immunocytochemical analyses of hepatocyte nuclei from mice fed on genetically modified soybean. Cell Struct Funct. 2002; 27:173–80. doi: 10.1247/csf.27.173.
15. Séralini GE, Clair E, Mesnage R., Gress S., Defarge N., Malatesta M., De Vendômois J. S. Long term toxicity of a Roundup herbicide and a Roundup-tolerant genetically modified maize. Environ Sci Eur. 2014; 26(1): 1-14. doi: 10.1016/j.fct.2012.08.005.
16. Waltz E. Under wraps are the crop industry's strong-arm tactics and close-fisted attitude to sharing seeds holding back independent research and undermining public acceptance of transgenic crops? Nat Biotechnol. 2009; 27(10):880–882. doi: 10.1038/nbt 1009-880.
17. Maghari, B. M., Ardekani, A. M. Genetically modified foods and social concerns. Avicenna J Med Biotech 2011; 3(3): 109-117. doi: 10.5812/ijb.19512.
18. Benbrook C. Evidence of the magnitude and consequences of the Roundup Ready soybean yield drag from university-based varietal trials in 1998: Ag Bio Tech InfoNet Technical Paper Number 1. Sandpoint, Idaho; 1999. Available at: http://www. mindfully.org/ GE/RRS-Yield-Drag.htm.
19. Elmore RW, Roeth FW, Nelson LA. Glyphosate-resistant soyabean cultivar yields compared with sister lines. Agron J. 2001; 93:408-412. doi: 10.2134/agronj 2001.932408x.
20. Ma BL, Subedi KD. Development, yield, grain moisture and nitrogen uptake of Bt corn hybrids and their conventional near-isolines. Field Crops Res. 2005; 93:199-211. doi: 10.1016/j.fcr.2004.09.021.
21. Fernandez-Cornejo J, McBride WD. The adoption of bioengineered crops. Agricultural Economic Report No. 810. Washington, DC: US Department of Agriculture; 2002. Available at: http://www.ers.usda. gov/publication-s/aer810/aer810.pdf.
22. Fernandez-Cornejo J, Wechsler S, Livingston M, Mitchell L. Genetically engineered crops in the United States. Washington, DC: US Department of Agriculture; 2014. Available at: http://www.ers.usda. gov/ publications. doi: 10.2139/ssrn.2503388.
23. University of Canterbury. GM a failing biotechnology in modern agro-ecosystems [press release]. 2013. Available at: http://www.gmwatch.org/index.php/ news/rss/14802. doi: 10.1080/14735903.
24. Schroder M., Poulsen M., Wilcks A., Kroghsbo S., Miller A., Frenzel T., Shu Q. A 90-day safety study of genetically modified rice expressing Cry1Ab protein (*Bacillus thuringiensis* toxin) in Wistar rats. Food Chem Toxicol. 2007; 45: 339-349. doi: 10.1016/j.fct. 2006.09.001.
25. Trabalza-Marinucci M, Brandi G, Rondini C, et al. A three-year longitudinal study on the effects of a diet containing genetically modified Bt176 maize on the health status and performance of sheep. Livest Sci. 2008; 113:178–190. doi: 10.1016/j.livsci.2007.03.009.
26. Séralini GE, Mesnage R, Clair E, Gress S, de Vendômois JS, Cellier D. Genetically modified crops safety assessments: Present limits and possible improvements. Environ Sci Eur. 2011; 23(1): 1-10. doi: 10.1186/2190-4715-23-10.

27. Yum HY, Lee SY, Lee KE, Sohn MH, Kim KE. Genetically modified and wild soybeans: An immunologic comparison. Allergy Asthma Proc. 2005; 26:210-216. doi:10.1016/S0091-6749(03)81294-0.

28. Aris A, Leblanc S. Maternal and fetal exposure to pesticides associated to genetically modified foods in Eastern Townships of Quebec, Canada. Reprod Toxicol. 2011; 31(4): 528-533.doi: 10.1016/j.reprotox. 2011.02.004.

29. Mesnage R, Defarge N, de Vendomois JS, Séralini GE. Major pesticides are more toxic to human cells than their declared active principles. BioMed Res Int. 2014; 22(1), 35–67. doi: 10.1155/2014/179691.

30. Marc J, Mulner-Lorillon O, Belle R. Glyphosate-based pesticides affect cell cycle regulation. Biol Cell. 2004; 96: 245-9. doi: 10.1016/j.biolcel.2003.11.010.

31. Hardell L, Eriksson M, Nordstrom M. Exposure to pesticides as risk factor for non-Hodgkin's lymphoma and hairy cell leukemia: Pooled analysis of two Swedish case-control studies. Leuk Lymphoma. 2002; 43:1043-9. doi: 10.1080/10428190290021560.

32. Benbrook C. Impacts of genetically engineered crops on pesticide use in the US – The first sixteen years. Environ Sci Eur. 2012; 24: 1-13. doi: 10.1186/2190-4715-24-24.

33. Howard P. Visualizing consolidation in the global seed industry: 1996–2008. Sustainability. 2009; 1: 1266-1287. doi: 10.3390/su1041266.

34. Benbrook CM. Rust, resistance, run down soils, and rising costs - Problems facing soybean producers in Argentina. Technical Paper No 8. Ag Bio Tech InfoNet; 2005. Available at: http://www.greenpeace.org/raw/content/international/press/reports/rust-resistence-run-down-soi.pdf.

35. Zanatta M. Avanço da soja transgênica amplia uso de glifosato. Valor Econômico. 2007. Available at: http://www.seagri.ba.gov.br/noticias.asp?qact=view&exibir=clippingid=9931.

36.Knispel AL, McLachlan SM, Van Acker RC, Friesen LF. Gene flow and multiple herbicide resistance in escaped canola populations. Weed Sci. 2008; 56:72-80. doi: 10.1614/WS-07-097.1

37. Gassmann AJ, Petzold-Maxwell JL, Keweshan RS, Dunbar MW. Field-evolved resistance to Bt maize by Western corn GMO Myths and Truths 250 rootworm. PLoS ONE. 2011; 110(3), 287-293. doi: 10.1371/journal.pone.0022629.

38. Wang S., Just DR. Pinstrup-Andersen P. Bt-cotton and secondary pests. Int J Biotechnol. 2008;10:113–121. doi: 10.1504/IJBT.2008.018348.

39. Tabashnik B. E., Brévault T., Carrière Y. Insect resistance to Bt crops: Lessons from the first billion acres. Nature Biotechnol. 2013; 31(6), 510-521. doi: 10.1038/nbt.2597.

40.Kremer RJ. Glyphosate affects soybean root exudation and rhizosphere microorganisms. Int J Anal Environ Chem. 2005; 85: 1165–1174. doi: 10.1080/03067310500273146.

41.Fernandez MR., Zentner RP., Basnyat P., Gehl D., Selles F., Huber D. Glyphosate associations with cereal diseases caused by Fusarium spp. in the Canadian prairies. Eur J Agron. 2009; 31:133–143. doi: 10.1016/j.eja.2009.07.004.

42. Diaz-Llano G., Smith TK. Effects of feeding grains naturally contaminated with Fusarium mycotoxins with and without a polymeric glucomannan mycotoxin adsorbent on reproductive performance and serum chemistry of pregnant gilts. J Anim Sci. 2006; 84(9):2361-6. doi: 10.2527/jas.2006-213.

43. Lusk J. L., House L. O., Valli C., Jaeger S. R., Moore M., Morrow J. L., Traill W. B. Effect of information about benefits of biotechnology on consumer acceptance of genetically modified food: Evidence from experimental auctions in the United States, England, and France. ERAE, 2004; 31(2), 179-204. doi: 10.1093/erae/31.2.179.

44. Costa-Font M., Gil J. M., Traill W. B. Consumer acceptance, valuation of and attitudes towards genetically modified food: Review and implications for food policy. Food Policy, 2008; 33(2), 99-111. doi: 10.1016/j.foodpol.2007.07.002.

45. Gómez-Barbero M, Rodríguez-Cerezo E. Economic impact of dominant GM crops worldwide: A review. European Commission Joint Research Centre: Institute for Prospective Technological Studies; 2006. Available at: http://ftp.jrc.es/EURdoc/eur22547en.pdf.

46. Haq Z. Ministry blames Bt cotton for farmer suicides. Hindustan Times. http://bit.ly/IrPRRZ. Published March 26, 2012.

47. O'Callaghan M., Glare T. R., Burgess E. P., Malone L. A. Effects of plants genetically modified for insect resistance on nontarget organisms. Annu. Rev. Entomol. 2005; 50, 271-292. doi: 10.1146/annurev.ento.50.071803.130352.

48. Nap J. P., Metz P. L., Escaler M., Conner A. J. The release of genetically modified crops into the environment. The Plant Journal. 2003; 33(1), 1-18. doi: 10.1046/j.0960-7412.2003.01602.x.

49. Neuman W. Rapid rise in seed prices draws US scrutiny. New York Times. http://www.nyt-imes.com/2010/03/12/business/12seed.html?r=1.Published March 11, 2010.

50. Greenpeace. Children and infants in China at risk of eating food contaminated by illegal GE rice. http://www.greenpeace.org/eastasia/press/releases/food-agriculture/2011/ge-rice-baby-food/. Published April 20, 2011.

51. Greenpeace and Gene Watch UK. Germany finds unauthorized genetically modified (Bt63) rice noodles. GM Contamination Register. http://bit.ly/1nEKmEO. Published June 15, 2011.

52. Greenpeace and Gene Watch UK. Sweden finds unauthorized genetically modified (Bt63) rice. GM Contamination Register. http://bit.ly/1kXDCSP. Published June 27, 2011.

53. New Zealand Food Safety Authority (NZFSA). Unauthorized GM rice product found and withdrawn. http://www.foodsafety.govt.nz/elibrary/industry/Unauthorised_Rice-Zealand_Food.htm. Published July 30, 2008.

54. Organic Agriculture Protection Fund Committee. Organic farmers seek Supreme Court hearing. 2007. Available at: http://bit.ly/1iGdQla.

56. Netherwood T., Martin-Orue SM., O'Donnell AG. Assessing the survival of transgenic plant DNA in the human gastrointestinal tract. Nat Biotechnol. 2004; 22:204-209. doi: 10.1038/nbt934.

57. Pontiroli A., Simonet P., Frostegard A., Vogel TM., Monier JM. Fate of transgenic plant DNA in the environment. Env Biosaf Res. 2007; 6:15-35. doi: 10.1051/ebr:2007037.

58. Konig A., Cockbum B., Crevel P. W. R., Dbruyne E., Grafstroem R., Hammerling U., Kimber I., Knusden I., Kuiper H. A., Poulsen M., Schauzu M., Wal J. M. Assessment of the safety of foods derived from genetically modified (GM) crops. Food Chem Toxicol, 2004; (42): 1047-1088. doi: 10.1016/j.fct. 2004.02.019.

59. Mallarkey T. 2003. Human health concerns with GM crops. Mut Res. 544: 217-221. doi: 10.1016/j.mrrev. 2003.06.001.

60. Bellaloui N., Reddy K., Zablotowicz R. M., Mengistu A. Simulated glyphosate drift influences nitrate assimilation and nitrogen fixation in non-glyphosate-resistant soybean. J Agri Food Chem. 2006; (54) 3357-3364. doi: 10.1021/jf053198l.

61. Brookes G., Barfoot P. Global impact of biotech crops: Socio-economic and environmental effects in the first ten years of commercial use. Ag Bio Forum. 2006; (9)139-151. http://www.agbioforum. org/v9n3/ v9n302-brookes-.htm.

62. Otsuka Y. Socioeconomic considerations relevant to the sustainable development, use and control of genetically modified foods. Trends Food Sci Tech, 2003; 14: 294–318. doi: 10.1016/S0924-2244(03) 00077-3.

63. Herman E. M. Genetically modified soybeans and food allergies. JEB, 2003; 54(386), 1317-1319. doi: 10.1093/jxb/erg164.

64. Nordlee JA., Taylor SL., Townsend JA., Thomas LA., Bush RK. Identification of a Brazil-nut allergen in transgenic soybeans. New Engl J Med. 1996; 334:688-92. doi: 10.1056/NEJM199603143341103.

65. Samsel A., Seneff S. Glyphosate's suppression of cytochrome P450 enzymes and amino acid biosynthesis by the gut microbiome: Pathways to modern diseases. Entropy. 2013; 15:1416-1463. doi: 10.3390/e15041416.

66. Mazza R, Soave M, Morlacchini M, Piva G, Marocco A. Assessing the transfer of genetically modified DNA from feed to animal tissues. Transgenic Res. 2005; 14:775–84. doi: 10.1007/s11248-005-0009-5.

67. Bohme, H., Aulrich, K., Daenicke, R, Flachowsky, G. Genetically modified feeds in animal nutrition. 2nd communication: Glufosinate tolerant sugar beet (roots and silage) and maize grains for ruminants and pigs. Arch Anim Nutrit. 2001; (54) 197-207. doi: 10.1080/17450390109381978.

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