

Current Status of Genetically Modified Crops in Iran and the world: Overview of Production and Consumption Challenges

Abolfazl Baghbani-Arani (✉ abolfazlbaghbani@pnu.ac.ir)

Payam Noor University

Mona Poureisa

Payam Noor University

Hossein Alekajbaf

Payam Noor University

Rezvan Karami Borz- Abad

Payam Noor University

Khodadad Khodadadi-Dashtaki

Payam Noor University

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Abstract

Transgenic technologies expanded in many countries regarding the nutritional needs of the increasing population. There are, however, some concerns about possible risks in growing genetically modified (GM) food such as threats of biodiversity and food allergies making it a challenge. This study aimed at examining the economic effects and political scopes of GM food in the production sector and policies made by different countries in the world and Iran. Moreover, essential (practical and legal) solutions and guidelines for GM food production and consumption are provided, which are useful for governmental entities and Iranian politicians and consumers' rights. Transgenic technology has been accepted by high-rank farmers to produce genetically modified crops due to an increase in net profit caused by improved yield in spite of the high cost of transgenic seeds. Among 11 countries producing GM crops in the world in 2018, the USA is the first country followed by Brazil and Argentina at second and third ranks. In 2018, 78, 76, 30 and 29% of soybean, cotton, corn and canola production areas respectively were under cultivation of GM varieties. Although Iran has been one of the leading Asian countries not only in the field of transfer of technical knowledge of genetic engineering, but also in the development of specialized knowledge of biosafety, and despite the production of several transgenic plant lines by Iranian researchers, no GM crop has obtained release and cultivation license except for genetically modified rice that its growing process was banned after government change. This study implies that GM crops growing and production process does not follow the global trend owing to scientific and legal infrastructures.

Introduction

Food security is one of the most significant human challenges in facing population growth and climate change risks. World population of the world is about 7.5 billion people now and about 83 million people are adding to the number annually; however, it has been estimated to about 8.5 billion and 9.7 billion people by 2030 and 2050, respectively. Such rise in world population is the key reason for global poverty (1). UN FAO (Food and Agriculture Organization) reported food shortage among 795 million people in 2016 that 780 million of them are living in developing countries (2). Therefore, starvation eradication should be the prior policy of countries. Now, increase in crops yield in cultivated area may be the most realistic solution to meet the increasing global demand for crops. Nevertheless, FAO predicts that the cultivable lands for food products will decline from present value of 0.242 hectares per person to 0.18 hectares by 2050. Such problem leads to double population growth and malnutrition challenges (2). However, some countries such as Iran have limited capacity to expand the area under cultivation (3). Therefore, more agricultural inputs such as fertilizers, water, pesticides, or genetic improvers should be used to achieve higher yield per hectare (4). In this regard, several other complex factors include increasing demand for biofuels and production of raw materials and global warming, accelerated urbanization, desertification, salinization and erosion of arable soil, land use change in accordance with economic considerations, climate change and limited water resources arise (1).

Scientific innovations in plant biotechnology and quantitative advances in farm management are powerful tools used to cope with abovementioned challenges. Farmers has been always improving the

genetic of crops unconsciously by choosing the best product for their future production. The conventional breeders have performed successfully in improving quality and quantity of crops using genetic knowledge; nevertheless, there are some constraints in traditional methods for plant breeding. Genetic engineering is a complementary but powerful tool that can help breeders overcome these limitations, making it the fastest-accepted technology in agricultural history (5). More than 60 years ago, the human imagination about biology was changed after discovery of DNA structure (physical factor determining inheritance and traits) leading to progress in genetic planning. Emergence of DNA modification technology in 1944 helped scientists to find that genetic material can be transferred to different species. Genetic engineering received a considerable attention from scientific and practical studies along with progress in gene transfer procedures and polymer chain reaction (PCR) methods during 1980s. GM organisms have been defined by WHO (World Health Organization), FAO, and European commission: organisms (ie, plants, animals, or microorganisms) in which the genetic material has been altered in a way that does not occur in natural recombination or mating. This definition tries to present a new concept of direct manipulation of genetic organisms, which differs from the conventional performance of improving genetic traits of plants and animals that has been done with selective modification over thousands years. Recombinant DNA technology is used to transfer genes from an organism to another unrelated organism (6, 1). The first genetically modified plants were antibiotic-resistant tobaccos and Petunia produced by three separate research groups in 1983. Chinese scientists first commercialized genetically modified tobacco in the early 1990s. In 1994, the US market saw the first genetically modified tomato species (FLAVR SAVR) with delayed ripening and Food and Drug Administration approval. Since then, several GM products such as canola with modified oil and pesticide-resistant types of cotton and soybeans have obtained the USA FDA license. (1, 7).

Gm Plants: Advantages And Disadvantages

There has been increase of more than 400 million tons food products during 1992-2014. One seventh of increased yield is attributed to GM products produced in USA. To achieve this increase in yield related to transgenic plants, it is estimated that more than 300 million hectares of conventional crops are needed (8). This additional area should include lands requiring more water and fertilizers or tropical forests that should be destroyed to achieve this goal. Such destruction leads to serious environmental concerns globally. Toxins and pesticides not only impose a heavy cost on household and national levels but also threat health of farmers and consumers owing to remnants of pesticides. On the other hand, chemical pesticides have irreversible effect on non-target organisms like natural enemy (9). For example, *Bacillus thuringiensis* known as Bt is bacteria, which kills insects and is used all around the world to control plant pests particularly larva of Lepidoptera (butterflies and moths), Coleoptera and larva of blindness-carrying mosquitoes in Africa. As these bacteria generates a crystalline protein, is used to control pests. When this protein is consumed by insects it is activated in insect's stomatogastric system and converts to delta endotoxin, which finally removes the pest while not harming humans, plants, wildlife (10). It is clear that this technology, by eliminating the need to use chemical toxin, serves the environment and economic savings of farmers (11, 3). On the other hand, most of the GM species are resistant against herbicide or

pesticide. Accordingly, it would be possible to remove pesticides or reduce their use in farming; such reduction definitely leads to economic and environmental advantages. On the other hand, reducing the amount of toxin consumed has the advantage that the farmer can use the no-till system more easily (6, 12, 3). As a result, it reduces the amount of eroded soil, provides more protection for plants, and reduces the use of farm equipment. Genetic engineering of plants can promote phytoextraction of metals and metalloids from soil by their accumulation in the aboveground biomass (13). Some of environmental stresses such as drought, hot or cold weather, salinity of water or soil may lead to economic damage to plants as well as significant decline (up to 70%) in crops, fruits, and vegetables (14). By identifying the genes of resistance to these stresses and transferring them to crops, it is possible to prevent a severe reduction in yield in stressful environments such as Iran (6). In the current situation in which Iran is in a water crisis and since about 80 to 90% of the country's water consumption is for agricultural purposes, these products have a significant impact on reducing water consumption and preventing its wastage (15). Increasing the profit from cultivating transgenic plants due to increasing yield and reducing the use of pesticides (16), modifying the chemical composition of food to eliminate malnutrition (1, 17), improving food processing (18, 19, 1, 20, 21) Finally, the use of genetic engineering to produce plants that can be used as oral vaccines (22, 23, 24) is another benefit of transgenic plants. On the other hand, because this technology works with living organisms, in interaction with other living organisms, the risks are more dangerous and unpredictable than experiments using chemicals (20, 25). Some concerns about safety of these products for human health and environment due to possible risks caused by gene, genetic drift, adverse effects on non-target organisms, emergence of resistant weeds and insects (6) and threats of biodiversity (26, 27), and on the other hand the dangers of genetically modified foods such as antibiotic resistance in humans (20) and allergies to these products (20, 28) raise concerns among opponents of transgenic plants.

Religious reasons may be also expressed as concerns about GM foods. According to Raman (29), there are various orders given by different religions about these foods. Halakha (Jewish Law) has accepted the genetic engineering as a method to improve quality or increase amount of food in the world; while there is not any consensus on advantages of GM foods or any study on consuming these foods in Christianity. In Islamic viewpoint, it is not required to modify foods genetically as the God has created anything in its perfect form so human is not allowed to manipulate anything that has been created by divine wise (29). However, another study quoted from great imitation authorities and Leader of Islamic Republic of Iran that GM foods can be consumed if are not harmful for health (30).

Organogenetic products: The nexus between organic agriculture and genetic engineering

However, use of chemical pesticides is not justifiable due to scientific progress and GM plants production; accordingly, more than 40 new varieties of pesticide and herbicide-resistant plants have been approved and cultivated in 2019 all around the world (31). For instance, herbicide (Randap)-resistant soybean provides a higher yield of 5% compared to non-resistant soy. Moreover, there will be less soil harm and higher productivity owing to fewer spraying frequency for herbicide-resistant soy. Herbicide-resistant soybean technology led to 5.2 billion dollars increase in agricultural revenue during 2014 and a 46.6

billion dollars income rise since 1996, which can be named as the highest economic profit obtained from GM plants among consumer countries (8). Moreover, the seeds carrying pests-resistant Bt gene have reduced the 40 to 80% use of insecticides for GM potato and cotton, respectively. This decline leads to reduction in use of raw materials such as the fuels used in pesticide production and transportation industries as well as decrease in spraying frequencies (32). Hence, "Organogenetic" is defined as the interconnection of organic and GM products (33). This term has been introduced to show common goals of organic agriculture and GM plants production. In fact, genetic engineering and production of GM plants is an advance technology, which is used by humans cleverly to alleviate harms caused by pesticides and to produce healthy safe foods. There would be an inevitable relationship between GM and organic products under the title of food security-based "Organogenetic products", which reduces human concerns about increasing rate of world population (34).

Although organic agriculture provides lower performance than conventional farming, it produces products with the same nutritional quality or even higher-quality products with lower remnants of pesticides. On the other hand, there might grow a high number of saprophytic fungi in organic products caused by pests or diseases leading to toxic or carcinogenic mycotoxins. Therefore, an integration of conventional and modern methods in agriculture and new sciences and technologies can be used as a solution for food and environmental problems in order to produce cost-effective food for growing population of the world and Iran and to help retail and low-income farmers with their life expenses. Such methods alleviate environmental effects caused by agricultural activities (5). This goal cannot be achieved by improving common farming methods but by using genetic improvement and modification (creating sustained and yielding varieties) through plant biotechnology (35).

Biotechnology development in agriculture and technology acceptance by farmers

GM plants were marketed as foodstuffs about one decade after producing the first generation of GM plants in laboratory (36). In many countries where farmers are free to choose technology, conventional crops have been replaced with genetically modified plants. For example, corn, cotton and soybean can be named as GM crops in USA with more than 90% acceptance for biotechnological products. The same case has occurred for soybean in Brazil and Argentina, cotton in India and China and canola in Canada (36). There has been a considerable rise in acceptance of pesticide-resistant GM sugar beets in USA. Farmers could reduce frequent spraying and subsequently save more time and money by controlling weeds growing in areas under the cultivation of pesticide-resistant sugar beets. As this method is cost-effective, farmers accepted different kinds of biotechnology within a short time (37).

Many studies have been done to find why farmers prefer GM crops to conventional ones. Klümper and Qaim (2014) reported an average 68% and 22% increase in farmers' profits and product yield, respectively and 39% reduction in cost of pesticides after using biotechnology-produced crops (38). In general, such increased yield and profit was higher in developing countries compared to developed countries. Therefore, farmers achieve an economic profit despite the high cost of seeds used for biotechnological plants. In

addition to economic advantages, farmers justify the use of such plants due to other non-monetary benefits such as saving time, ease of use, and more flexible planning (39, 40).

Important role of GM crops used as food in many of countries

About 70-90% of produced GM crops in the world are used to feed livestock (41). In USA, with the high acceptance of these products, more than 95% of animals, which are used as human foods, are feed by GM plants. More than 100 billion livestock have been fed over the past decade. Health and performance of the livestock was also studied and there was not any adverse effect caused by feeding livestock with GM crops compared with ordinary foods given to animals (42). There is a low global demand for unapproved GM plant nutrition. Market share of soybean has been estimated to be lower than 4.4% and about 7% of transacted corns are unproved. Extensive acceptance rate of transgenic varieties in major exporting countries indicates that more than 90% of produced soybeans in the world are genetically modified. In the EU, too, the majority of soy-based livestock feed contains genetically modified components. (43, 42).

Statistics of GM plants in the world (2016-2019)

There has been a 112-fold increase in the land area under the cultivation of transgenic products from the early commercialization year 1996 to the end of 2018 reaching from 1.7 million hectares in 1996 to 189.8 million hectares in 2018 (Figure 1). Statistics imply a global rise in GM products so that 26 countries (19 developing and 7 industrial countries) cultivated GM plants in 2016 when 6.99 million hectares of lands (54%) in developing countries and 5.85 million hectares (46%) in developed countries was allocated to GM products. The highest rate of cultivation area is allocated to soybean with 91.4 million hectares about 50% of total areas used for GM plants. In 2016, 78% of soybeans, 64% of cotton, 26% of corn and 24% of rapeseed were transgenic based on the total yield per capita. The area under cultivation for products with multiple transgenic traits reached to 4.75 million hectares in 2016 with 29% rise that 41% of total production areas was allocated to GM products. At that time, 93% of this area was related to 6 countries including developing countries (Brazil, Argentina, India) and developed countries (USA, Canada). With 9.42 million hectares of lands under the cultivation of GM crops (38%), USA was at the first place in 2016. Brazil with 1.49 million hectares (28%), Argentina with 8.23 million hectares (14%), India with 8.10 million hectares (7%), Canada with 6.11 million hectares (6%), and China (2%) were ranked as second to sixth countries. Totally, 93% of areas were allocated to GM plants (8).

Global value of transgenic seed market was estimated to 8.15 billion in 2016, which experienced 3% increase relative to previous year. This value was about 22% of total market share of pesticides (5.73 billion dollars) and 35% of commercial seeds (45 billion dollars) in the world during 2016. It is estimated that the income obtained from seeds and other GM products had been 10 times greater than transgenic seeds. Estimation indicates the 230 billion dollars value of final GM products, which are directly used by human or livestock. There was 574 million tons (167.8 billion US dollars) increase in GM products during 1996-2015 while this value reached to 75 million tons (4.15 billion dollars) only in 2015 (44). Global value of GM seed reached to 17.2 billion dollars in 2017, which indicates a 9% growth (about 15.8 billion

dollars) in global value of biotechnologically produced crops in 2016. It is anticipated this value experiences a 10.5% growth by 2025 (45).

There is a substantial growth in main GM products in 2017 compared to 2016 indicating following rates for these products: 79% of global areas allocates to soybean (94.1 million hectares), 32% to corn (59.7 million hectares), 80% to cotton (24.21 million hectares), and 30% to canola (10.2 million hectares).

Commercial use of GM crops expanded to new products such as sugar beets, papaya, squash, eggplant, potato and apple in 2017 (*Malus pumila* Miller, 1768), which were marketed in USA (46, 47). Eggplant as the most consumed vegetable and potato as the fourth main product of global agriculture are the plants that their GM cultivars were grown and consumed. GM products can be marketed as food and livestock feed but a wide range of these products such as corn, soybean and canola are used as human foods and livestock feed. Most of the GM products have been approved as GM foods that are directly used by humans except for alfalfa (*Medicago sativa* L. ssp. *sativa*) and Schoenoplectus (*Agrostis stolonifera*). Alfalfa is the first transgenic product marketed in USA. Developing countries have been producing more biotechnology products during past seven years. In 2018, 21 developing countries planted 54 percent (103.1 million hectares) of global biotechnology hectares, while 5 industrialized countries accounted for 46 percent (88.6 million hectares).

It is predicted that this trend continues due to increase in number of countries in southern part of earth that begin to produce biotechnology-based agriculture and commercialization of new biotechnology products such as rice that grows in developing countries (45). Among 26 countries that have cultivated biotechnology products in 2018, 18 countries have been the pioneers of this trend that have increased the rate by allocating 50.000 hectares of lands to such products. USA is the top producer of biotechnology products in the world by allocating 75 million hectares to these products covering 39% of global crops under the biotechnology method; Brazil is ranked as the second country by allocating 51.3 million hectares (about 27% of global production) (Figure 2). Soybean, corn, cotton and canola were the most cultivated biotechnology products in 2018. Although only a 2% increase in cultivation of GM soybean is seen, but it has maintained an acceptance rate above 50% that is about 95.9 million hectares of lands. These areas include about 78% of total soybean production in the world (Figure 3).

GM corn allocated 58.9 million hectares (30%) of global production to itself in 2018 (Figure 3). The minor decline (1%) in GM corn production compared to 2017 has occurred due to inappropriate climate in Latin America, low market price, new pests, and emergence of fake seeds in Philippine. The 3% increase in total production of GM cotton in the world is attributed to improved global market value and more acceptance of pesticides-resistant GM seeds. GM canola experienced a 1% decline in USA and Canada in 2018 owing to lower demand in northern hemisphere of the world (Figure 3).

American and Canadian farmers planted 1.26 million biotechnology alfalfa in 2018 with 3.3% increase relative to 2017. About 1.14 million hectares of lands in USA was allocated to pesticide-resistant-alfalfa and 120.000 hectares was allocated to low lignin-content alfalfa, while 4000 hectares of lands was allocated to low lignin-content alfalfa in Canada. Low-lignin alfalfa was marketed in 2016 for first time

with a 15-20% yield increase. In addition to soybean, corn, cotton, canola and alfalfa, some other GM products such as papaya, eggplant, potato, apple, safflowers, pineapple, and sugarcane have been cultivated in 2018 (31). GM products have been highly accepted in recent years. A new record of 191.7 million hectares of lands was allocated to these plants in 2018. Nevertheless, there is a slow rate of increase in the area allocated to GM products. There has been only 1% increase in 2018 compared to 2.54% increase in 2017 and 3% rise in 2016.

The average acceptance rate of GM crops (soybean, corn and canola) in 2018 was about 93.3%, 93%, 100%, 92.5%, and 95% in USA, Brazil, Argentina, Canada, and India, respectively (45). This industry now is experiencing a recession period, which its constant growth depends on deregulation in new markets, Research and development of new product. In 2019, 43 Gm plants that covered 40 species all around the world were approved (Table 1) (31, 48). The number of modified and approved has been reduced compared to two years earlier.

Current Position Of Gm Products In The World (Case Studies: America, Europe, Asia And Africa)

In 2016, 6 Asian countries produced GM crops; China produced cotton and papaya, India produced pests-resistant cotton, Pakistan produced pests-resistant cotton, Myanmar produced pests-resistant cotton, Philippine and Vietnam produced pests-resistant and pesticide-resistant corns. In the continent of America, USA as the biggest producer of GM products in the world, some countries such as Brazil, Argentina, Canada, Bolivia, Paraguay, Uruguay, Mexico and Burkina Faso produced GM crops. In Africa, South Africa joined countries supporting GM products since 2000 and now is cultivating GM corn, soybean and cotton. Australia is also a leading country in transgenic technology that produced GM cotton in 2016 and added pesticide-resistant canola to its agricultural products in 2018 (32). In 2017, however, 24 countries producing GM crops included 12 countries in America (with 88% production areas in USA, Brazil, Argentina, Canada, Paraguay, Bolivia, Uruguay, Mexico, Colombia, Honduras, Chile and Costa Rica), 8 countries in Asia and Pacific Ocean (with 10% area under the cultivation by India, Pakistan, China, Australia, Philippine, Myanmar, Vietnam, and Bangladesh), two European countries (with 0.5% area under cultivation by Spain and Portugal), and two African countries (1.5% area under cultivation by South Africa and Sudan) (49).

China (unusual acceptance of GM plants)

The Ministry of Agriculture and Rural Affairs of China ordered to publish safety license of modified organism in terms of agriculturally modified organism to 192 plant varieties in 2019 included 189 cotton varieties, two maize varieties, and soybean variety, which led to a possibly better future for seed industry of China and approved 5 new GM crops such as pesticide-resistant canola and pesticide-resistant soybean as well as 26 existing GM crops. It was the second time of issuing health certificate for GM crops to be used as food during the past decade; the first time was 2009 when health certificates had been issued for GM corn and rice.

According to “Regulations on Administration of Agricultural Genetically Modified Organisms” and relevant guidelines, approval of GM seeds in China is subject to evaluation of safety of these products. Seed production should be allowed by Agriculture Administration of Ministry of Foreign Affairs regarding commercial cultivation of GM crops. However, seed producers have progressed industrialization of GM crops in 2019. In February 2019, GM Glyphosate and Glufosinate-resistant soybean was produced under the LTD Argentina license as the first GM crop produced by Chinese company, which tends to acquire international license to cultivate this product in Uruguay and Brazil. China tends to commercialize the GM seed industry but not in China; Chinese companies want to cultivate this crop overseas. In addition, it has been allowed to reimport such products to ensure food security in China (31).

There are few data from many of geographical areas while there are numerous studies on GM products and consumer attitude toward these crops in Europe and North America (40). There are interesting conditions in China where, the government spends high cost to develop GM crops as an investment in food industry. Pests-resistant GM cotton is widely cultivated with more than 90% acceptance rate in China. China started to trade GM rice about 10 years ago. The results of pre-field experiments with pest-resistant transgenic rice showed higher crop yield and sever reduction in the use of pesticides. These factors also led to positive health effects on farmers. Regulations on mandatory labelling foods produced by GM products have been enforcing more than one decade (22). China’s government invested in development of biotechnology products and announced a 3.5 billion dollars-program for GM products in 2008. But in the last five years, people's attitudes toward these products have become more ethically negative. Meanwhile, it seems commercialization of GM rice has been stopped in China. In August 2014, biosafety certificates of two GM rice lines issued in 2009 were expired without any renewal leading to illegal cultivation of these plants and raises speculation as to whether the Chinese government will cancel further development of transgenic rice.

Nonetheless, certificates of this product were renewed for 5 years in January 2015 (51). In February 2015, the main document No.1- the first important document of annual policies that was published by central committee of communist party- obliged the government to support researches pertained to GM technologies, particularly for crops. On the other hand, Chinese scientists should conduct more studies to convince people who are concern about advantages of GM products (40, 52). Accordingly, consumer attitudes toward GM plants play a vital role in policies made in the world. Generally, studies conducted in China indicate that consumers have a positive attitude toward GM foods in China, particularly if these products have high quality. However, there has been an increase in number of consumers who worried about GM foods in China so the government acts cautiously (31).

India

India had to increase farming productivity and production in order to supply food and income for an increasingly growing population. Department of Biotechnology under the Ministry of Science and Technology of India was established in 1986 to promote and support biotechnological applications. Generally, there is an active scientific trend toward agricultural biotechnology researches (53). The

introduction of pest-resistant cotton for commercial production in 2002 was protested by several NGO groups claiming that the product was inefficient or even unsuccessful, however, these public claims were not scientifically examined and GM cotton cultivation became a great success story in India so that about 95% of areas allocated to cotton was cultivated by GM lines in 2014 (16). Genetically modified cotton could reduce dependence on chemical pesticides, increase yield and profit of retail farmers within a sustained and long period, and lead to a positive socioeconomic progress in India. Increasing farmers' income led to increase in food security for Indian cotton farmers. There are more than 1000 cotton cultivars with resistance to pests and proper genetic backgrounds for available local conditions. Such big choice preserves agricultural biodiversity in India; and available GM products have not led to any reduction in various types of cotton cultivated by Indian farmers. GM species (brinjal) and hybrids were approved in 2009 by the Genetic Engineering Approval Committee of the Ministry of Environment after 9-years extensive agricultural and safety tests such as large-scale field experiments. However, protests of anti-transgenic activist made Minister of Environment of India to declare GM cultivation as an illegal action because there was not any specific self-confidence in studies related to state safety and risk assessment; on the other hand, there were possible health risks caused by GM products and concerns about dominance of foreign technology and missing food sovereignty. Such decision had a highly negative effect on active Indian research society so that only 10 GM plants (cotton, pea, sorghum, sugarcane, castor, rice, and potato) with different specifications were developed during 15 years; however, laboratory tests were illegal and there was not any clear future for GM products test out of the specific laboratory until 2014. Development of GM products was limited in India and the government's approach to cultivating transgenic crops seems to be much more cautious than research, and the need to improve the regulatory framework for biotechnology products is obvious (53). India's developments are monitoring by the world as they reflect the debates on using GM products in many of developing countries that should keep balance between new technologies and need of agricultural efficiency (54).

Pakistan

The modern biotechnology was performed for the first time in Pakistan in 1985. So far, 56 advanced biotechnology research institutes (50 public and 6 private organizations) have been established in Pakistan; most of these organizations tend to increase genetic potential. The modified products have been used more to help farmers with biotic and abiotic environmental stresses. Genetically modified Cry1Ac-containing cotton (Mon-531) is the only GM product recommended for general cultivation in Pakistan. As Pakistan has signed Cartagena Protocols on Biosafety, national biosafety regulations under the safety rules were approved in 2005 in this country to design researches related to development and commercialization of GM products. The license for first GM plant (cotton) was issued in 2010 in Pakistan; and there has been a considerable progress in plants biotechnology and introduction of GM plants in this country. Pests-resistant cotton was introduced in Pakistan then another version of pests-resistant GM cotton was added in 2012 and two pesticide-resistant and pests-tolerant corn species were introduced in 2017 (55).

Turkey

Turkey benefits from rich genetic resources so “biodiversity degradation” is considered as the most important risk for use of genetically modified products. It is believed in Turkey that it is not possible to restore GM organisms in nature after they were consumed and lack of information in this field may harm genetic resources. Therefore, this substantial issue should be considered in rules. Production and cultivation of GM organisms is forbidden in Turkey. According to Biosafety Act of Turkey, it is banned to produce GM crops. The GM products formulated in foods of children and infants, supplements for infants older than 6 months and children are banned based on the rules enacted by Ministry of Food, Agriculture, and Livestock. Although there are no restrictions on the application of these provisions in all EU countries and the United States, Turkish authorities have banned such use with a precautionary approach to protect future generations. There are severe fines considered for those who violate this rule in the market. According to Article 15 of Turkish Law entitled fines, importers or producers of GMOs in the environment are sentenced to 5-12 years prison and a governmental fine of 10.000-200.000 Turkish Liras based on the type of the crime committed against the law (not notifying the biosafety council). GMOs export from and import to Turkey is monitored. The monitoring system is based on the specific methods and rules for crops with and without genetic alteration. According to this law, GM crops should be labelled based on the decision made by biosafety institution upon arrival. Therefore, it is not possible to introduce or supply GM crops within ambiguous methods against public opinions; in Turkey, complete information has been inserted on these products to make consumers aware of the difference between GM and non-GM products. Hence, consumers have right to choose products. Biosafety Act was introduced in Turkey to solve problems related to GMOs law absence. The combined management of pests and weeds with integrated crops control has been considered in Turkey as an option for genetic usages in order to increase quality and efficiency as well as sustainable agricultural development and food safety (18).

GM crops in USA and Europe (their disagreement as the largest and smallest countries producing and consuming GM crops in the world)

Considering the severe regulatory space in EU, only one type of GM plant (pests-resistant GM corn) is allowed to be cultivated in the EU. Spain is the only European country with many farms growing GM products. Farmers have had good experiences and high economic yield in field of GM corn efficiency compared to ordinary corn in regions contaminated with pests since introduction of this technology in 1998 (56). In 2018, 35% and 6% of total areas of Spain and Portugal, respectively (about 121.000 hectares of lands) has been allocated to GM corn. There is low amount of GM corn cultivated in four other European countries (Portugal, Czech Republic, Romania, and Slovakia).

A study was conducted on economic and environmental effects caused by acceptance and use of pests-resistant GM corn in Spain and Portugal over the 21 years (1998-2018). It was found that of total 1.65 million hectares of cultivated corn (from 1998 to 2018), 1.89 million tons of extra produced corn using less resources and subsequent lower stress on scarce resources such as water led to 285.4 million Euro in farmers' income compared to growing non-GM corn. Each extra 1Euro spent for GM seed leads to 4.95 Euro extra incomes for farmers obtained from higher yield (11.5% in both countries by using this

technology). This seed technology has led to a reduction of 678000kg active substance (37%) and subsequent decline in environmental effects caused by pesticides and herbicides used for crops. Moreover, this technology has contributed to low fuel consumption, less emission of greenhouse gases in the area under the cultivation of GM crops, and water saving (57).

However, total area under the cultivation of GM crops in Europe has been equal to 143000 hectares of lands (a small part of global area allocated to GM products) in 2014. GM corns are not associated with needs of local farmers in other European countries where its cultivation is disappointing or totally banned (36). However, cultivating pests-resistant GM corn in EU has been approved, but many of EU member states have relied on the regulations enacted by EU (412/2015), which allows the countries to ban this technology due to non-scientific reasons (57). Another considerable case was herbicide-resistant GM soybean in Romania, which its cultivation was began in 1999 as a new solution to control weeds that its acceptance by farmers led to an average increase of 30% in product yield making it the most profitable crop in Romania. About 137.000 hectares of lands in Romania was allocated to growing genetically modified soybean in 2006 covering 68% of soybean production in EU. Increased yield of farms led to rise in soybean production in Romania so that it could be exported to other European countries, while soybean meal import was reduced considerably. When Romania joined EU in 2007, GM soybean was not allowed to be grown or consumed; hence, farmers had to cultivate conventional seeds. Due to the sharp decline in the profitability of common seeds, soybean sown area fell by 70% in two years, making Romania, like other European countries, dependent on expensive soybean imports, and in general, Romanian farmers lost a very profitable crop (58). Although GM crops are not cultivated in European countries, farmers have a positive attitude toward crops genetically modified by biotechnology. A survey indicated that more than half of German farmers and almost half of farmers in Czech and UK are willing to obtain the license for herbicide-resistant plants as this technology facilitates weeds control process. More than one third of Spain, French and Hungarian farmers tend to use herbicide-tolerant GM corn (59). Another study showed that many of farmers in UK announced their willingness to cultivate GM corn, canola or sugar beet with the governmental permission (60). However, this does not occur in EU. According to reports proposed by European countries, there is high amount of GM foods imported and consumed because it ultimately helps produce their food. On the other hand, when about 80% of the world's soybean crop is transgenic, European countries, whether they like it or not, import it (40). But GM products were widely consumed in livestock feed and food markets after introduction of these products in USA market in 1996. USA authorities had adopted and approved a permissible policy for GM foods without any need to label GM plants. Furthermore, majority of American consumers were less worried about GM foods and agricultural biotechnology in the years following introduction of these products so that they used to purchase foodstuffs produced from GM plants despite the limited knowledge of consumers about GM foods.

Remarkable point is that the entrance of the first carriage of GM soybean from USA to Europe in 1996 faced a severe protest by environmental NGOs. There has been a considerable change in social and regulatory framework at both side of Atlantic Ocean leading to a direct impact on consumer attitude. In contrary to USA, EU approved strict requirements in this case. It has been approved in EU to label GM

foods- even if genetic modification in final product was identified- since 1997 (61). Moreover, foods purified from GM plants such as oils or sugars have been labelling since 2003 even if these products are physically or chemically similar with non-GM products (50, 43). EU now has set a certain regulatory framework for cultivating, consuming and importing GM products for livestock feed and foodstuffs (62, 63). There is a challenging issue about permissions pertained to growing and importing GM crops and plants owing to domestic disagreements between EU member states and lack of a consensus on the case (64). Such challenge has led to prolonged decision-making process to issue license for biotechnological products. Major food exporters in EU should spend on average 15 to 20 months more than required time in USA, Brazil and Canada to acquire permission; this has led to import disruption in EU (36). Although NGOs usually play lesser role in USA, these organizations have performed successfully in introducing GM plants as a threat to biodiversity, farmers' independence and food safety in Europe (40, 65). These groups and supporters of political green parties and organic movement have focused on possible risks and negative effects of GM foods. These groups and parties use such orientations in election campaigns, papers and media. In general, social and political conditions of Europe justify the negative attitude of European consumers toward GM foods compared to consumers in Northern America (61, 65). There is a low acceptance of GM plants among European politicians and consumers, in particular in Germany while the rules governing the market licensing and labelling foods produced from GM products in USA are based the scientific logic and "basic equivalence" concept. If there is an unmodified substance in composition of a new GM food, it does not require labelling as such label does not include the information about product specifications. Federal Food and Drug Administration of USA has set binding labelling only if the GM food has different nutritional properties and allergies (61, 65). There are fewer rules related to GM foods in USA relative to EU and these regulations are more permissive in USA than in EU (66). A few numbers of social American activists protest against biotechnological demands for food production. The first public initiative for GM foods labelling in Oregon State in 2002 was rejected due to votes given by more than 70% of voters. Seemingly, the end of anti-GM plants in USA in 2008 led to expansion of GM products cultivation and consumption (67). However, anti-GMOs movement has been experiencing a considerable trend since then leading to social discussions on GM crops and foods. Opposition to GM crops and foods is beyond the scientific concerns about food safety including a wide range of environmental and sustainability as well as social and economic aspects. It seems that GMOs has raised extensive ethical concerns about sustainable agriculture and foodstuffs. The powerful coalition of NGOs, environment and consumers, organic farming proponents and food producers and ethic-based retailers asks for mandatory labelling of GM products and modern biotechnology-based foods. They argue that consumers have right to know about the nature of foods they consume; they should be able to choose whether buy foods with or without GMOs based on a transparent food system. Respect for consumer rights, however, cannot provide the only legal basis for mandatory food labelling in the United States. Majority of food industries in USA are opposed to mandatory labelling as it increases unessential costs without any advantage for consumer safety. In fact, the consumer will have fewer options by removing GM products from USA market like Europe conditions (40).

GM food labelling in USA and other countries (to ensure consumers rights)

GM foods have been the most debatable global issue over the recent decade so that EU insists on information disclosure for consumers while USA is against such request. It seems there is changing trend in global concern from primarily concerns about risk toward democratic sovereignty of "right to know" versus "need to know" (68). GM food labelling policy includes forbidden labelling, voluntary labelling (indicating that a product is GM ingredient-free), or mandatory labelling that shows a GM ingredient-contained product. Legal threshold is determined through labelling process, which is different in countries leading to complex goods commerce and transportation (41). For instance, there is 5% tolerance threshold for foods and livestock feed in USA, Canada, and Japan, while this rate is about 1% in Australia, New Zealand, Southern Africa, Brazil and China. In EU, however, a marketed product containing greater than 0.9% of GM ingredients is labelled as a GM product and consumers should know this information (69). Most countries have set the mandatory labelling rules, while USA authorities consider the nature of product more important than the production process so voluntary labelling is accepted for GM products (70). According to existing rules, it is not mandatory to label GM product- including products prepared from livestock fed by GM feed (such as meat, milk and egg)- and GM supplements and enzymes (such as rennet for cheese production) (71). However, some of EU countries have set rules and regulations on voluntary labelling of livestock products as GM products allowing consumers to choose products producing without direct use of GM ingredients (72). In 2016, President Obama signed an act entitled national bioengineering foodstuffs standard, which ended the debate on labelling GM foods in USA. This act became binding in 2020 and will be enforcing up to January 2022. According to this Act, any product containing GM ingredients or byproducts should be labelled inserting this information. After January 2022, any GM labelled product is considered as GM ingredients container. In 2019, Bioengineered (BE) labels stuck on sold products in food stores of USA could be found. According to the new law, the products manufactured by new techniques such as CRISPR, TALEN and RNAi should also be labelled. Moreover, livestock feed are not exceptions, while meat, egg and dairy products containing GM ingredients are not bind to labelling standard. Moreover, it is not required to express or disclose the foods purified and extracted from GM products unless they contain traceable GMOs. Beet sugar, soybean oil and corn sweeteners that are generally produced from GM seeds should not be labelled as GM constituents. In 2019, the GM products approved for marketing in USA include Salmon fish (AquAdvantage), apple, Canola, corn, cotton, eggplant, papaya, pineapple, potato, soybean, pumpkin, and sugar beet (31).

Argentina

Argentina was ranked as the third country with about 100% of acceptance rate among 10 countries in the world 2018 in terms of cultivating GM products with 23.9 million hectares under cultivation including 18 million hectares of GM soybean, 5.5 million hectares of GM corn, and 0.37 million hectares of cotton. In the last few years, a few number of GM products have been approved in Argentina. However, governmental support has accelerated cultivation rate so that about 25 new GM traits in plants have been introduced and approved in this country. Eight GM crops such as corn, soybean and alfalfa were approved in 2018 and this number reached to 12 in 2019, which one third of global approvals in this year cover six GM corn traits, three GM soybean traits and three GM cotton traits. On October 2019, the sixtieth

GM product was introduced and approved after the first approval in 1996. In addition, Argentina pledged to support intellectual property rights and introduction of advanced technologies for GM cotton in favor of domestic cotton production in order to remove the technological gap between Argentina and Brazil; in this case, three new Glyphosate herbicide-resistant GM cotton traits were approved. The first registration of GM potato in Argentina (PVY-resistant SPT TICAR) was begun in 2021 to start producing GM potato (31).

Generally, there has been an increasing trend in acceptance of GM crops by millions of farmers over the recent decades in countries where GM species are available. A considerable amount of globally marketed GM products is based on the GM plants. Since 1994, 65 countries have issued GM import and export licenses (36). Apparently, there is a high acceptance rate in market for global use of GM products as livestock feed. Even according to reports given by European countries, high amounts of GM feed are imported to and consumed in Europe, which has contributed to increase in foodstuffs production (43).

About 525 various GM lines in 32 products was approved in different regions of the world up to 2019. It has been proved that GM technology has led to rise in product yield, decline in pesticides and herbicides, reduction in CO₂ emission, and decline in production cost of crops. However, there are serious barriers to the high acceptance of GM external genes-containing products due to concerns about possible toxicity and allergic effects on human, probable environmental risks such as negative effects on non-target organisms, and strengthening weeds and pests. Such concerns have led to emergence of other types of modifications such as cisgenesis, intragenesis, and genome editing as an alternative to transgenesis. In cisgenesis and intragenesis, genetic elements being deployed for crop improvement via transformation belong to same or closely related species, i.e. from sexually compatible gene pool. Genome editing can also be developed using gene knockdown or gene knockout to alter the genetic makeup of a plant without incorporating genes from other plants. Creation of a strain of wheat that is resistant to powdery mildew is an example of the use of this method. Hence, it is expected that these products obtain more acceptance rate by consumers and acquire regulatory approvals more rapidly compared to GM products (6).

GM plants in Iran (Challenges, Practical and Legal Solutions)

Agriculture sector in Iran has been one of important and relatively stable economic sector of Iran with about 14-15% share of GDP despite the unprecedented sanctions over the recent years. Moreover, this sector includes about 20% of employment rate in Iran while only 5% of direct employment of individuals in developing countries allocates to agriculture sector. Hence, agriculture sector is the most important part of Iran's economy (73). On the other hand, along with the increase in life expectancy, the population of Iran is expected to reach 95.3 million at the lowest level and more than 112 million at the highest level in 2031. Therefore, it is essential to develop various crop species with enriched nutrients and high resistance to biotic and abiotic stresses considering the increasing population rate, small arable lands, high employment rate in agriculture, increasing climate change rate, global warming and current droughts (74). In Iran similar oppositions may be seen in NGOs, eco-friendly institutions, and high management levels. opponents of genetic engineering development are trying to prevent from such technology

although national law on biosafety forces the government to facilitate GM products release, cultivation, production, consumption, import and export. This means that the conventional method for crops production is going to be continued. Iran has been one of leading countries in Asia not only in transferring genetic engineering knowledge but also in developing biosafety science. Iranian experts participated in first meetings of advisory committee of Cartagena biosafety protocol and Iran has been one of first Asian countries joined this protocol (74). Some biosafety actions have been done in Iran including establishment of the first scientific biosafety association among Asian countries, designing and approving Biosafety Act, establishing National Biosafety Council, forming specialized secretariats in three ministries, founding a governmental organization, enforcing assessment mechanism, issuing environmental release, import and export licenses for GM products. Although there have been numerous infrastructures and achievements in field GM products commercialization and production, Iran cannot be named as a success story (5). Despite the successful production of several GM plants in field experiments by Iranian researchers, there has not been any GM product with release permission expect for GM rice that was formally released in 2004 but its production was banned after government change. Lack of scientific governance and national benefits-based approaches to plant genetic engineering as well as debatable issues in this field can be named as reasons for such significant inconsistency between Iran's capacities and genetic engineering technology achievements (74). More than 99% of crops are produced in Iran using conventional agrochemical methods. There is lower than 1% organic production rate in Iran. Therefore, chemical toxins are essentially used in Iran's farming technology. Despite the dramatic growth of GM plants in the world and excessive use of chemical pesticides by Iranian farmers and legal emphasis on the government's obligation to provide required facilities for GM plants production and consumption (Biosafety Law), this is still a debatable issue due to opposition of some Iranian managers who are not aware of this technology. These managers argue that GM products may have negative impacts on human health and environment. Adeli and Ghareyazi (9) carried out a study and found that 90% of pesticides are used to control crop pests while these pests are controlled by GM plants in the world. Moreover, reduction in these toxins (human health and environment) brings numerous advantages for farmers who use these seeds. Moreover, repetitive use of insecticides makes insects resistant to previous forms. Cultivation of GM rice in Iran is the practical example for controlling Asiatic rice borer. There are several GM rice species to control this pest. There was a global rise in GM products in 1996 and Iran also began to produce Asiatic rice borer-resistant GM rice, (highest amount of toxin is used in rice cultivation to combat it). Such achievement in Iran received a considerable attention from the world as this rice called "Taram Moulae" is the first GM version of rice released in the world and the first GM product produced in Muslim countries and Middle East which has reached the field. Hundreds of Iranian farmers have produced this rice but it has been banned due to biosafety concerns; therefore, farmers used a higher concentration and new compositions of insecticides- due to resistance of pests and inefficiency of pesticides- to control these pests. Accordingly, these GM seeds could reduce the use of pesticides and environmental contaminations and control natural and useful insects living in rice fields such as ladybirds and fishes. In particular, these seeds could solve the problems of farmers due to contact with such toxins (41). The issue of monitoring the type and amount of pesticides used in agricultural products is an important and sensitive issue that is not done in Iran as it should be. Rice

cultivation in north provinces of Iran is one of main source for livelihood of farmers. Numerous pests existing in rice fields have led to sever crop loss in this area (75); hence, it is essential to use pesticides and other chemical toxins in current rice cultivation so that 60% of total use of pesticides in Iran allocates to north provinces that its dominant cropping pattern is rice (76). Reports indicate that pests control is usually done using chemical toxins among farmers in north of Iran. Excessive use of pesticides is harmful for useful living insects and organisms in farms so that a high rate of gastrointestinal cancer caused by chemical toxins used in agriculture might be seen in these provinces. On the other hand, chemical pesticides are using increasingly due to their economic benefits, availability, efficiency and flexibility and there might not be any possible reduction in their use rate (9). In addition, their effectiveness in controlling pests indicates their acceptable function; hence, farmers tend to use chemical pesticides because they are not aware of negative effects in human health and environment (76). Since the Asiatic rice borer cause a 4-6% hurt to the produced rice and 2.9 million tons rice had been produced during 2018 (with 36 Kg consumption per capita), 1000 tons of rice should be imported to keep market equilibrium and support strategic storage of country (77). Accordingly, this rate of GM rice varieties (Bt) can supply strategic rice reserves and prevent from rice import and currency outflow. Iran became one of producers of GM products in 2004. Although GM rice production was stopped in 2006, two GM goats called Shangool and Mangool were born by diligent researchers in Royan Institute under the supervision of Iran's leader in 2009 and this was a success for researchers of modern biotechnology in agriculture sector (78). Iranian researchers have achieved some successes in the field of GM plants including Bt gene transfer to Iranian Rice (Taaram Moulaei), GM cotton and potato production, and pests-resistant gene transfer to sugar beet and alfalfa. GM alfalfa that generates cry3A gene and resists against alfalfa weevil was created for the first time in 2014 by Tohidfar et al. (79). In case of GM animals, Iranian researchers could access to the technology of coagulation factor protein IX existing in milk of Iranian goat for Hemophilia B patients and another protein in Iranian goat's milk to generate heart attack medicine (78).

On the other hand, Iran is the importer of oil, forage, and corn that are sold as GM products in the global market. It should be noted that only about 10% of soybean derivatives including vegetable oils, soybean flour, lecithin, and soybean protein is non-GM in market of many countries. Moreover, GM grains exist in 20% of marketed cereals and their derivatives such as starch and cereal flour and more than 90% of these foods are produced supplied out of the labelling EU processes and standards, which are the most binding rules in the world. GM foods are going to be produced in future; for instance, rice, sugar, tea, and sugar beet will be added to the list. However, livestock feed is the main market of GM products (80, 81). On the other hand, Iran highly depends on import of the main global GM products (soy, cotton, corn, and canola) and more 90% of vegetable oil with the highest area under cultivation in the world is imported. According to statistics, about 2300 thousand tons of total 2700 thousand tons of vegetable oil consuming in Iran include imported oil and oilseeds (about 2 million and 150.000 tons of soy, 80.000 tons of canola, and about 55 tons of sesame seed). In 2018, 78% of globally cultivated soybean and 29% canola were genetically modified so that even EU countries have imported the oil produced from GM plants despite the strict rules adopted for GM plants in Europe. Therefore, vegetable oil-importing countries- such as Iran- have to import these foodstuffs. On the other hand, more than 8 million tons of livestock corn has been

imported to Iran in 2019. This livestock feed has been exported from 18 countries of the world such as USA that is livestock corn exporter. Accordingly, 2225 tons of livestock corn has been imported to Iran from USA, which equals 500.000 USA dollars. USA is the largest producer of GM products in the world by allocating about 30% of global market share to itself during 2019 (82).

Ministry of Health and Medical Education of Iran declared in 2019 only three transgenic of genetically modified products including oilseeds of canola, soybean and corn as allowed products; there is not any other GM product in Iran's market and the named products also should have been labelled. It was also reported that total soybeans imported to Iran are genetically modified and Iranian people are consuming GM plants over 15 years. On the other hand, more than 6 million tons of corn, livestock and poultry feed imported to Iran are genetically modified; however, there is also GM cottonseed for oil production in Iran's market. Hence, the Head of Department of Environment and main member of Biosafety Council (2019) explained that there is not any scientific document on risky effects of GM foods on human health in Iran and world arguing that excessive pressure on resources is riskier than production and consumption of GM foods (83). Now, Iran's food and drug administration has predicted to main provisions on import of GM products to Iran; first, the GM product should be used in producing country and second, the product should have an international license with a transparent GM and genetic manipulation process. For example, even a corn byproduct imported to Iran that is GM or non-GM should have a valid license in both cases. In the case of GM product, it should present a license to prove the type of GM as well as consumption permission in producing country. A GM product should have an international license obtained from USA FDA or European Food Safety Authority (EFSA) (84). Furthermore, about 50-60% of cotton is imported to Iran while 80% of the lands under the cotton cultivation in world are allocated to GM varieties (31). Moreover, international organizations such as Food and Agriculture Organization, WHO (World Health Organization), EU Commission, French Academy of France, American Medical Association, and American Toxicology Association have examined the safety of foods produced from GM plants and approved their food safety for human health (85, 74). According to the economic and environmental advantages and human health of GM plants, the required licenses for cultivation of these products should be given to farmers based on the biosafety law approved by Islamic Parliament, global food standards and protocols, and tasks assigned to beneficiaries by Biosafety Act to track and test food security of GM products. Furthermore, consumer has right to know which product is genetically modified. GM labelling is a solution used to alleviate concerns about these products. Although there are disagreements on labelling GM foods and microorganisms, it seems that GM food producers and microorganisms as well as biotechnology owners will insists on GM labelling as these labels can represent the high quality of GM foods (25). For instance, high oleic acid-containing GM soybean producers claim that their product contains less saturated fat so is more suitable for consumption. Therefore, the consumer's trust will be won if there is accessibility to real and neutral information about GM foods and GMOs given to consumers (86).

As it was mentioned, religious attitude of individuals may affect the GM product acceptance. This is an important challenge in using results obtained from genetic engineering studies and production of GM plants or organisms consumed by people. Despite the concerns raised in Islamic principles, there is not

any dissuasive rule for genetic alteration in plants and animals. There have been various opinions about consumption of GM products in Islam and there is not any consensus on acceptance of these products. According to research results, in Islam (Shia religion) referring to Islamic experts' viewpoints, consumption of GM products is unrestricted, provided that these are safe and health produces as natural foods. In addition, bioethics has been considered by Islamic authorities. They believe that GM products and relevant studies and technologies to them are permissible if safety and ethical aspects are respected. Such provisions are based on the proper structures and mechanisms. Seemingly, there are suitable structures such as Department of Environment, Plant protection Organization and other executive organization in Iran that play a vital role in this field. The abovementioned organizations cooperate with national biosafety council and Biotechnology Development Headquarter. It is hoped to achieve a proper mechanism in executive acts due to approval of national biosafety law.

Genetic Modification and associated standards in the world and Iran

Many of international organizations have paid attention to challenging issue related to GM product consumption by proposing some principles, standards and guidelines to increase safety and decrease concerns about these products. Cartagena Protocol on Biosafety can be named as the most important international binding standard and now 158 countries (such as Iran) are parties to the protocol (78). Cartagena Protocol on Biosafety associated with biological diversity convention is an international convention ruling over the behavior of GMOs resulting from modern biotechnology from one country to another one. This convention was accepted as an agreement attached to Biological Diversity Convention. The protocol defines a "living modified organism" as any living organism that possesses a novel combination of genetic material obtained using modern biotechnology, and "living organism" means any biological entity capable of transferring or replicating genetic material including sterile organisms, viruses, and bacteria. The objective of this protocol is to protect biological diversity against potential risks of living modified organisms resulting from modern biotechnology. This protocol creates an informed agreement to ensure countries with required information about entrance of such organisms to their territories before making informed decisions. Briefly, protocol covers options including required formal declaration on GMOs export, specific license before primary actions of transferring GMOs to other countries, essential information about public and international parties in case of a sudden reproduction, rule on exported processed food, nutrition or GMOs and identification of GMOs for export. According to Cartagena Protocol on biosafety, all of genetically modified organisms should be tested in terms of laboratory analysis, greenhouse and field assessments for product specifications, considered use, environmental impacts, and possible risks for human and animal health to make decision on their application, import and export. This decision is expressed in form of risk management including preventive measures. Countries should follow these regulations, approve safe use of GMOs, adopt required measures through control process and transportation, and enact some rules on GMOs' labelling and packing. This protocol has predicted some limits on regulations of free trade of GMOs through signing agreements with world trade organization (74). Primary mechanisms of Cartagena Protocol on Biosafety can be identified as information exchange, pre-announcement agreement, simplified process, risk assessment, documentations, decision-making, and risk management. Biosafety measures are done

based on the possible interaction between GMOs and environment to preserve biological diversity in Cartagena Protocol on Biosafety. To ensure biosafety, pre-announced agreement is signed between exporting and importing countries. All of countries are informed about converting food waste into animal feed and processed foods. Some statements and documentation should be inserted on the label or next to the lable of these products Which clearly indicate the following sentence "may contain genetically modified organisms" and should be noted that should not be left in the environment. Applicable regulations on GMOs are informed to countries and they can share this information with other countries. Domestic use of GMOs is not subjected to a pre-announced agreement and each country sets some standards based on their own conditions and informs the exchange method. The sign of "Genetically Modified" should be inserted on the label of these products besides information about how to use, keep, and transport cautiously. According to the existing laws, the safety assessment of such products is based on proving their comprehensive equivalence with unmodified types, as well as conducting specific tests in the field of sensitivity to proteins, toxicity of metabolites and food. Following Iran's accession to the Cartagena Biosafety Protocol, the process of drafting the Biosafety Law of the Islamic Republic of Iran began, and finally in 2009 this law was approved by the Islamic Parliament. Not only has this law allowed all of affairs associated with GMOs but also obliged the government to facilitate release, cultivation, production, consumption, export and import of Gm products regarding local technology based on the legal regulations (87, 88). Hence, an organization called "Biosafety Council" has been established in Iran by forming a secretariat in Department of Environment responsible for producing and supplying GM products (5).

Conclusion

GM products advantages include self-sufficiency in agricultural production, food security (considering increasing population rate and climate change in the world), human health and safety, and lack of environmental degradation. Cultivation of pests-resistant GM products can prevent from use of harmful chemical toxins and pesticides and drought tolerant plants can be grown to reduce and control harms caused by water crisis. Those plants with modified nutritional properties besides phytoremediation process in which GM plants can remove contaminants from the soil and water and many other examples indicate the vital role of GM products in environment and human health as well as other pros leading to high quality of life. On the other hand, increasing number of farmers who cultivate GM products in developing and developed countries implies the advantages of genetically modified products for crop production and farmers' income rate. Over more than 20 years after the introduction of GM products, 100 billion hectares of land have been under the cultivation of GM products and more than 18 million farmers have supported this technology. Such high acceptance rate indicates the trust of millions of farmers in biotechnology and GM technology. According to experiences of retail farmers who cultivate GM products in India, China, Pakistan, Argentina, and other developing countries, retail agriculture can also adopt this technology. Despite the advantages of GM plants and their global acceptance, Iran that imports the main four GM products in the world (soy, corn, cotton, and canola) but does not allow farmers to cultivate these products by employing experts based on the scientific and legal bases. Hence, there

should be a revision in rules prohibiting GM products in Iran. In general, it can be stated that agriculture and medicine industry are two main scopes for genetic engineering. Agriculture particularly plant breeding benefits from genetic engineering. The slogan of genetic engineering is “feeding the world and sustainability”, but there are many arguments about advantages of this technology. Consumers have created many concerns about human health, environment, animal wellbeing, and moral-religious acceptability. As there is low understanding of genetic engineering’s risks, the harms caused by GM crops should be studied precisely and be available to the public. The governments should have some rules about safety issues, labelling and detectability of these products. Hence, there should be a management system, legal attention and specific method to evaluate food toxins in natural and laboratory environment in order to test health of GM products and respect the right consumers. Seemingly, biosafety law of Iran binds production and development of these products to a small-scale area under the control; then GM products can be generalized to the whole country. Furthermore, Iranian researchers should consider different applications of genetic engineering in commercial market and design new methods to minimize biological and environmental risks of this technology. Although the genetically modified foods are marketing in international market based on the safety assessments, countries may behave differently in case of GM foods and this warns about necessity of global consensus on labelling and detecting GM foods considering health and environmental risks as well as religious issues.

Declarations

Authors’ contributions The first draft of the manuscript was written by Abolfazl Baghbani-Arani and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Tables

Table 1- New GM product approved in 2019 and the latest update in 2020.			
Approved use	Country/Region	GM Trait	Products
Food use	South Korea	Glufosinate & Glyphosate & 2,4-D HT, Lepidopteran IR, MM	Maize
Food use, Cultivation	Argentina	Glyphosate & 2,4-D HT	Maize
F&F	Philippines	Glyphosate & 2,4-D HT	Soybean
F&F	EU	Glufosinate & Glyphosate & 2,4-D HT, Lepidopteran & Coleopteran IR	Maize
F&F	China, Philippines	Glufosinate & Glyphosate & 2,4-D HT	Soybean
Food use, Cultivation	Argentina	Glyphosate HT, Drought stress tolerance	Soybean
F, F&C	Brazil		
Feed use, Cultivation	Japan	Glufosinate HT, Coleopteran IR, Multiple IR	Maize
Food use	Taiwan		
F&F	EU	Glufosinate & Glyphosate HT, Lepidopteran IR, Multiple IR	Maize
F, F&C	Argentina, Brazil	Glyphosate HT, Lepidopteran IR, MM	Maize
Food use	Japan, Taiwan	Hemipteran IR	Cotton
F&F	China	Glyphosate HT	Canola
F&F	EU	Lepidopteran IR	Soybean
Cultivation	United States	Modified oil/fatty acid, Imazamox HT	Canola
F, F&C	Brazil	Glyphosate & Isoxaflutole HT	Cotton
Food use	Taiwan		
F, F&C	Brazil	Glufosinate & Isoxaflutole HT, Lepidopteran IR	Cotton
F&F	China	Glufosinate HT, Fertility restoration	Canola
F&F	China	Glufosinate & Mesotrione HT	Soybean
F&F	China	Glyphosate & Isoxaflutole HT	Soybean
Food use, Cultivation	Argentina		

F&F	EU	Glufosinate & Glyphosate HT, Lepidopteran IR, AR, Visual marker	Cotton
F&F	EU	Increased Ear Biomass	Maize
F, F&C	Nigeria	Lepidopteran IR	Cowpea
F, F&C	United States	Non-Browning Phenotype, AR	Apple
F, F&C	Brazil	Lepidopteran IR	Sugarcane (CTC91087-6)
F, F&C	United States	AR, Low Gossypol	Cotton
F&F = Food and Feed use; F, F&C = Food, Feed and Cultivation; HT = herbicide Tolerant; IR = insect resistant; MM = Mannose metabolism; AR = Antibiotic resistance			

Figures

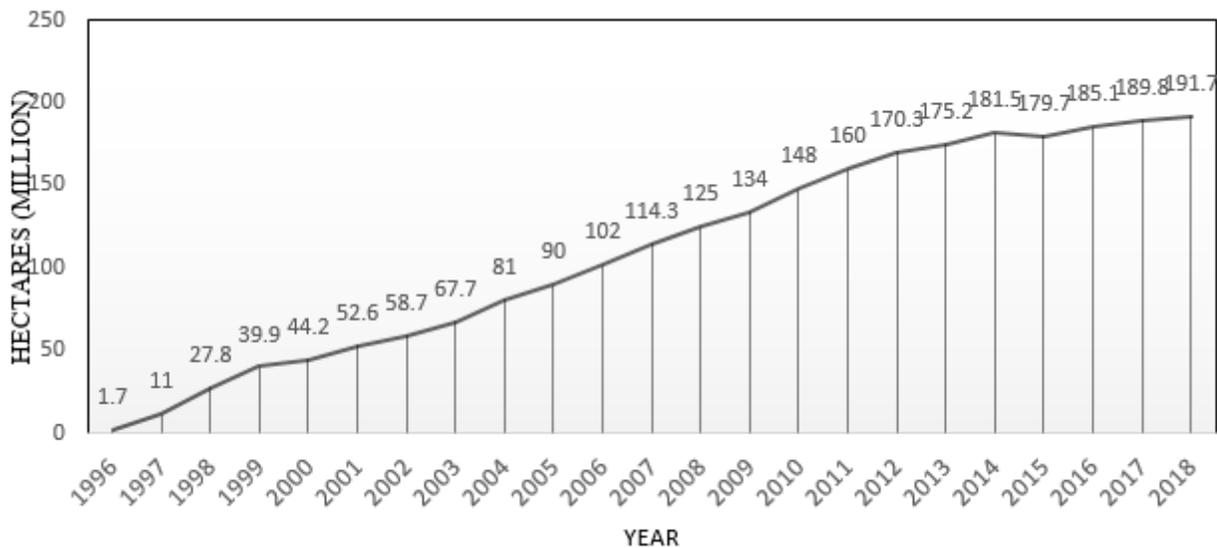


Figure 1

Global Area of Biotech Crops, 1996 to 2018

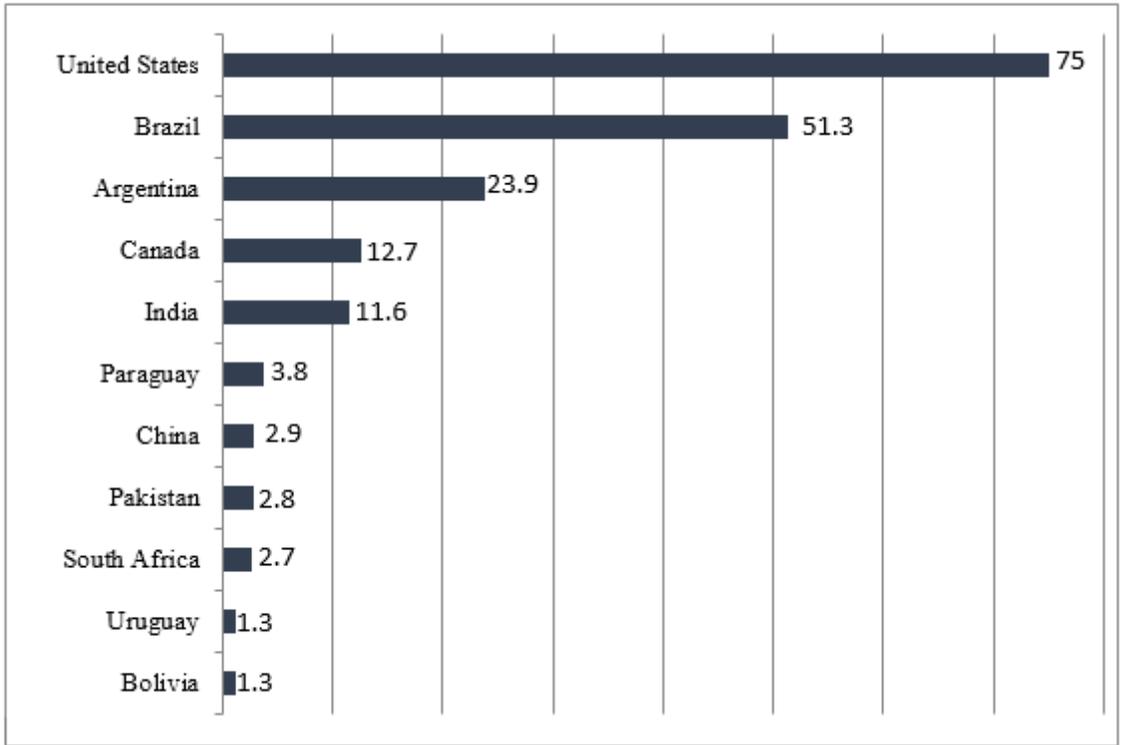


Figure 2

Area of genetically modified (GM) crops worldwide in 2018, by country (in million hectares)

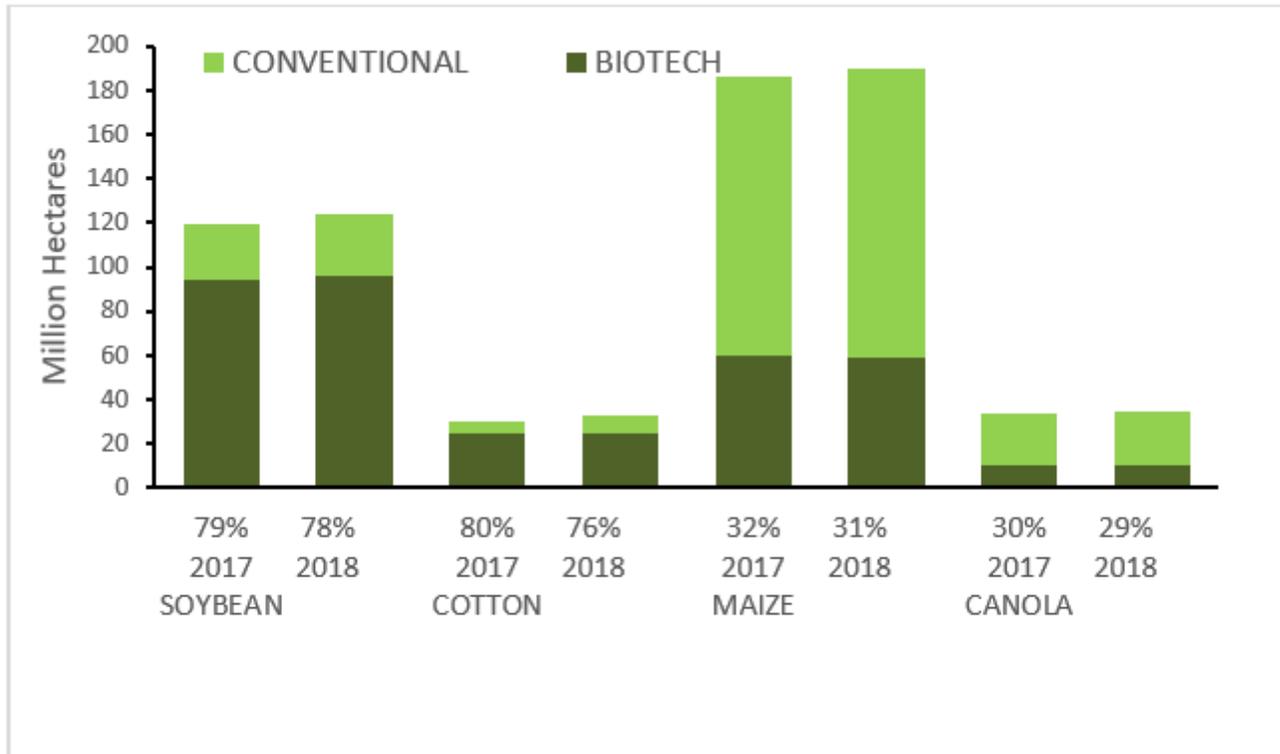


Figure 3

Global area and adoption rate (%) for top 4 Biotech crops (Million hectares). Source: ISAAA, 2018 (38)