Possible Benefits of Growing GM Crops in the European Union

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Abstract
The European Union has been very slow to embrace GMOs in comparison with most other countries, requiring extensive authorizations for use and especially crop cultivation, where only one Maize variety is currently approved. However, with more testing recent advances in Genetic Bioengineering and the current concerns regarding the global and European food supply, it is important to question whether the European scepticism surrounding GM crops is justified. Hence, the aim of this paper is to review the studies regarding GMO safety for use in food and feed and discuss the benefits of their large scale use in the European Union. Our results conclude that the extensive use and cultivation of GM crops in the European Union would be both beneficial and safe.

Keywords: European Union, crop regulation, GMO.

Introduction

Genetically modified organisms – GMOs – are living organisms like plants, animals or micro-organisms whose genetic material was altered artificially. This is done to either change the characteristics of these organisms, or to give them brand new proprieties or diverge the usual metabolic pathways. There are multiple types of gene engineering techniques such as OMICs [1], epigenetics and genome editing techniques, but they are used and applied only in the countries where the legislation admit this kind of modern technologies. The new techniques involved new genes insertion (knock-in gene), or genes from endogenous sources can be altered, enhanced or even made it inoperative (knockout gene).

To create GMOs the researcher must know very well what gene they want to modify, how they isolate it, how they will combine the gene for insertion with other genetic compounds, and which method is optimal, they also have to include a promoter and terminator marker, and finally, they can hope that the new strain created will meet their requirements and expectations.

Genetically modified organisms have been very successful in multiple fields, such as *medicine* – bacterial synthesis of animal and human hormones such as insulin [2] and somatotropin [3]; biochemical compounds important in coagulation process to treat haemophilia [4,5]; interferon against various forms of cancer or Covid-19 [6,7]; erythropoietin to treat or improving anaemia [8]; in *agriculture* – yields and quality improvement [9,10], improved resistance to insects and diseases [11]; and more recently also for *animal husbandry* with the introduction of genetically modified animals approved for human consumption (meat, eggs, milk) [12-14].

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With respect to crops designed for human consumption, that will be the focus of this paper, there have been ongoing debates regarding the possible safety concerns that appear from the gene editing process.

GMOs in the world

GMOs are seeing widespread use around the world, but due to the increased world population the demand for food is increasing by the day and GMOs could be – at least – a temporary solution. Regarding the International Sciences Survey 2019-2020, Q20 – Science and Scientists held in high esteem by the public worldwide. Across Global Public, out of 21 countries involved in the survey, for GMOs' unsafe to eat, Russia had the highest answers (70%), compared to Netherlands which has the lowest (29%), but the Netherlands also had the highest answers for "don't know enough to say" (50%) [15]. For certain crops, there are very good genetically modified alternatives that are much more viable economically and have a dominant share in production.

Globally, United States is the leader in GM crop production, with 71.5 million hectares (Ha) cultivated in 2019, followed by Brazil with 52.8 mil. Ha, Argentina with 24 mil. Ha, Canada 12.5 mil. Ha, India 11.9 mil. Ha, and Paraguay, China, South Africa, and Pakistan between 5-2 mil. Ha, in 2019 [16, 17].

In the United States the most cultivated GM crops covers the most part of the specific plant plantation, as GM sugar beets made up 99.9% of all planted sugar beets in 2013, GM cotton represented 96% of all planted cotton in 2020, GM canola made up 95% of all planted canola in 2013, GM soybeans represented 94% from all planted soybean in 2020 [18].

Also regarding very recent data, over 90% of US Fmaize and soybeans are GM, with the highest increase between 1996 and 2006, whereas GM corn started from 1.4% in 1996 and got to 40% in 2006 and 90% in 2022; and GM soybeans represented 7.4% in 1996, 89% in 2006 and in 2022 was 95% [19].

Compared to US, Europe and European Union have been a lot more cautious to embrace genetically modified crops than the rest of the world. Thus, for a crop to be eligible for import and consumption in the European Union, approval by the European Food Safety Authority (EFSA) and the Commission's Standing Committee on Plants, Animals, Food and Feed (PAFF) are needed [20]. Compared to US, other countries experience a far more complicated approval process. However, this authorization only covers use and imports, and does not include cultivation. For this, additional authorizations are needed [21].

The difficulty of this bureaucratic process is highlighted by the fact that only one GM strain, MON 810 Maize, is approved for cultivation inside the EU from 2018 [22]. And yet, even approved GM crops are limited further in regards to cultivation, because 19 out of the 27 member states of the EU have voted to opt out and ban any and all GM crop cultivation on their soil [23] – fig. 1.

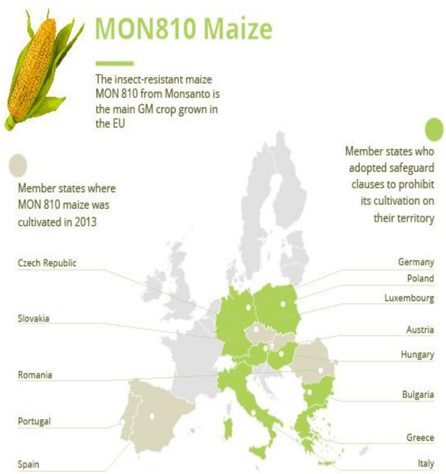

Figure 1. Mon 810 maize cultivation in Europe [24]

With the current climate crisis, together with UK Brexit, and lately war raging on in Ukraine – the "food basket" of Europe, generate concerns over European food supply. So, most of the countries have to think how to be more food and fodder self-reliant. Thus, European Parliament Members, and also political members of United Kingdom, started to express their truly support for the use of different genetic modification methods and techniques in new agricultural and animal farming biotechnologies.

European Parliament evaluates the scientific risk assessment in order to authorise the cultivation or sale for consumption in EU. In 1998 in Europe, maize MON 810 was authorised for 5 years for cultivation, but in 2013 eight countries (Austria, Bulgaria, Germany, Greece, Italy, Luxembourg, and Poland) banned GM cultivation on their territory [24]. On the other hand, Ukraine is one of the biggest agricultural trade partners of the European Union. It is also the biggest sunflower producer in the world, while being also a very important producer of wheat (rye, oats, other cereals, etc.) and vegetable oil plants, like rapeseed.

Benefits of GMO

GMOs have been a subject of considerable debate and research for the last years. While there are concerns and criticism related to GMOs, they also offer several potential benefits. Studies have shown that adopting GMOs crop can increase yields by up to 37% and farmer profits by 68% [25]. It's important to note that the benefits can vary depending on the specific GMO and its intended use.

Increased crop yields: One of the primary goals of GMOs in agriculture is to increase crop productivity. Genetic modifications can make crops more resistant to pests and diseases, which can result in higher yields [10].

Reduced pesticide use: Some GMOs have been engineered to produce their own insecticides, reducing the need for external chemical pesticides. Another benefit of GM crops is that many are developed to synthesise their own herbicide or insecticide. This has multiple effects: first, it increases the efficiency of the pesticide compared to normal application, leading indirectly to higher yields. Also, the economic aspects are very important due to the fact that the pesticides no longer need to be purchased and sprayed on the plants. This can lower the environmental impact and decrease the cost of pest control for farmers [26].

Improved crop tolerance to environmental stress: GMOs can be designed to withstand adverse environmental conditions, such as drought, extreme temperatures, or soil salinity. This resilience can help crops thrive in regions with challenging growing conditions.

Enhanced nutritional value: Genetic modifications can be used to increase the nutritional content of crops. For example, "Golden Rice" was engineered to produce higher levels of vitamin A, which can address vitamin A deficiency in regions where rice is a dietary staple [27].

Extended shelf life: Genetic modifications can make fruits and vegetables more resistant to spoilage, potentially reducing food waste.

Faster crop development: Traditional breeding methods can take many years to produce desired traits in crops. GMOs can expedite this process by introducing specific genes, saving time and resources.

Medical and pharmaceutical applications: GMOs are used to produce pharmaceuticals, vaccines, and medical treatments, such as insulin, vaccines, and cannabinoid levels. This biotechnology can provide more efficient and cost-effective methods of producing these substances [28].

Biofuels: Some GMOs are engineered to produce biofuels more efficiently, which can be a more sustainable and eco-friendly energy source.

Conservation of biodiversity: GMOs can be used to address conservation challenges by helping endangered species or ecosystems recover. The lack of GMOs crop cultivation in Europe risks to leave it behind in this very important research field of genetic engineering. For example, genetic modifications can enhance the disease resistance of species on the brink of extinction.

Reduced environmental impact: GMOs can reduce the need for tilling and other soil-disturbing agricultural practices, which can help preserve soil health and reduce erosion.

It's important to acknowledge that along with these potential benefits, there are also concerns about GMOs, including environmental risks, potential health impacts, ethical considerations, and intellectual property issues related to seed ownership and control [28]. Regulatory frameworks and ongoing research aim to address and balance these considerations. The benefits of GMOs depend on responsible use and ongoing evaluation of their impacts.

Sustainability: The benefits mentioned above also have ramifications impacting the sustainability of GM crops (fig. 2) [29, 30].

Figure 2. GMOs and Biotechnology's importance in sustainability

During the 1996-2014 period, herbicides use dropped by almost 600 million tons, reducing global emissions from herbicides and insecticides use by nearly 20%. Applying pesticides often requires vehicles, which leads to fuel consumption and vehicles, that increase the costs of production and important emissions with ecological impact on the environment.
It is estimated that the reductions in fuel use from this machinery had the equivalent effect of removing 12 million cars from the road [28]. Additionally, the higher yields of GM crops help diminish the risk of land use change due to agriculture, which helps protect biodiversity and reduce deforestation.

New GM technologies

New advances in the field of Genetic Engineering, such as the CRISPR-Cas9, ZFN, TALENS, LAGLIDADG technology, ensure minimal risks during the Genome Editing process [31].

CRISPR/Cas9 (Clustered Regularly Interspaced Short Palindromic Repeats/CRISPR-associated protein 9) – is a versatile and widely used genome editing technique. It relies on an RNA molecule called guide RNA (gRNA) to target specific DNA sequences. The Cas9 protein, guided by the gRNA, can cut the DNA at the desired location. CRISPR/Cas9 is used for a wide range of genetic modifications, including gene knockout (disabling a gene), gene knock-in (introducing a new gene), and gene editing in various organisms, from bacteria to plants and animals. More exactly, CRISPR-Cas9 is a regularly spaced short palindromic adaptation technique that uses a combination of proteins and short nucleic acid to target specific sequences in nucleic acid for cleavage. CRISPR organisms collect protospacers from foreign nucleic acid sequences, incorporate them into their own genome using them to express a short guide nucleic acid that can then be used by a CRISPR-Cas system to knock down any nucleic acid sequence that would fit protospacers [32].

ZFNs (Zinc Finger Nucleases) – are engineered proteins with zinc finger motifs that can bind to specific DNA sequences. They are fused with a nuclease domain to introduce double-strand breaks at the target site. ZFNs have been used for gene editing in various organisms, including plants, animals, and human cells. They are considered one of the early tools for genome editing. Zinc finger nucleases (ZFN) are frequently used in biomedical research providing the possibility of generating animal models for various industrial or medical-pharmaceutical applications. ZFNs are specialized fusion proteins characterized by multiple specific DNA binding domains. These proteins provided by transcription factors containing the zinc finger, being attached to the endonuclease domain of the bacterial FokI restriction enzyme. Each zinc finger domain has the ability to recognize a DNA sequence consisting of 3 to 4 bp, and the tandem domains have the ability to bind to an extended nucleotide sequence (multiples of 3 in length, more often from 9 bp at 18 bp), this being unique in the genome of the involved cell [33].

TALENs (Transcription Activator-Like Effector Nucleases) – are designed proteins that can be customized to target specific DNA sequences. They work by fusing a customizable DNA-binding domain derived from transcription activator-like effectors with a nuclease that can cut

DNA. TALENs have been used for genome editing in plants, animals, and even human cells. They are particularly useful for making precise modifications to the genome. TALEs - Transcription activator-like effectors are proteins that naturally comprise tandem arrays of 10 to 30 sequence repeats able to recognize and bind extended DNA sequences. Each sequence repeat comprises a number of 33 to 35 amino acids having two adjacent amino acids, which give specificity to one of the four DNA bp, where there is a one-to-one correspondence between the repeats and also in the base pairs of the target DNA sequences. Thus, it was created a new type of genetically engineered site-specific nuclease, that fuses a domain of TALE repeats to the FokI endonuclease domain. TALENs proteins are similar to ZFNs due to the possibility of generating in the genome DSBs at a desired target site, being used to knock-out genes or knock-in mutations in a similar way [31, 34].

LAGLIDADG (L1-encoded endonuclease) – is a DNA endonuclease enzyme found in mobile genetic elements called L1 retrotransposons. It can be used for targeted DNA cleavage and repair. LAGLIDADG-based editing has been used in research and genome engineering applications, but it is less commonly used compared to CRISPR/Cas9, TALENs, and ZFNs [35].

Modern genome editing (GE) techniques, such as CRISPR/Cas9, TALENs (Transcription Activator-Like Effector Nucleases), ZFNs (Zinc Finger Nucleases), and LAGLIDADG (L1-encoded endonuclease), have revolutionized the field of molecular biology and genetics by enabling precise and targeted modifications to an organism's DNA.

Conclusions

With modern technology – CRISPR-Cas9, ZFN, TALENS, growing GMOs is safer and more economically viable than ever, and we believe EU should also reap the advantages of GM crops, which bring benefits in production, safety, and sustainability.

All of these genome editing techniques are powerful tools for precise genetic modifications. CRISPR/Cas9 has gained significant prominence due to its simplicity, cost-effectiveness, and high precision. It has revolutionized genetic research and has numerous potential applications in fields ranging from medicine to agriculture. However, each of these techniques has its strengths and limitations, and the choice of which to use depends on the specific needs of a given experiment or application.

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