

Original Research Paper

GMOs, Start-ups & Food Security between the Promises of the Future and the Fears of Today

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Abstract

Few issues are hot topics for discussion such as those that deal with biotechnology in general and genetically modified organisms (GMOs) in particular. Fears and ambiguities about these are fuelled by myths and Hollywood movies. They are also promoted by environmentalists and anti-globalists of all stripes. This fear may be justified to some extent, but it is sometimes exaggerated. Therefore, through this research work, some of the concepts that revolve around biotechnologies and genetically modified organisms are clarified and discussed. The paper starts by giving an overview of the genetically modified organism market and its main players, then some promising start-ups will also be reviewed and discussed to reach the conclusion that these arguments anti GMOs are somewhat exaggerated, and that in no case should the fear about GMOs be generalised, because, under certain conditions and precautions, they can bring huge benefits to humanity, especially its securing food future security.

Keywords: Biotechnology, GMOs, Start-up, Transgenesis, Agro-industry, Malnutrition, Genetic pollution, Eugenics.

المخلص

قليلة هي القضايا التي أثارت ولا زالت تثير ضجة كبيرة، مثل التي أثارتها تلك المتعلقة بالتكنولوجيا الحيوية بشكل عام، وبالكائنات المعدلة وراثيًا على وجه الخصوص. ساهم في نشر هذه المخاوف الأساطير وأفلام هوليوود، وتبناها علماء البيئة، والمناهضون للعولمة من جميع الأطياف. وقد يكون لهذه المخاوف ما يبررها، لكنها أحياناً مبالغ فيها، ولذلك ومن خلال هذه الدراسة، سيتم توضيح بعض المفاهيم التي تدور حول التقنيات الحيوية والكائنات المعدلة وراثيًا، وإلقاء نظرة عامة على سوق الكائنات المعدلة وراثيًا، وعلى الفاعلين الرئيسيين فيها، على وجه الخصوص. وسيتم استعراض بعض الشركات الناشئة الواعدة، للوصول إلى استنتاج، مفاده أن هذه الحجج مبالغ فيها إلى حد ما، وأنه لا ينبغي بأي حال من الأحوال أن تؤخذ الكائنات المعدلة وراثيًا "بصيغة التعميم"، لأنها وفي ظل ظروف واحتياجات معينة، يمكن أن تأتي بفوائد جمة على البشرية وخاصة في ضمان مستقبلها الغذائي.

الكلمات المفتاحية: التكنولوجيا الحيوية، الكائنات المعدلة وراثيًا، بدء التشغيل، التخلق، الصناعة الزراعية، سوء التغذية، التلوث الجيني، تحسين النسل.

Introduction

The world population, as of January 01, 2022, is no less than 7.9 billion people and is growing on average by about 1.3% per year, which will bring the number of the total population of the planet to 10 billion inhabitants by 2040. But how to feed all these masses of people? There are already more than a billion and a half people, who suffer from hunger and malnutrition (including 800 million in Africa). Hunger, which at the beginning of this millennium is one of the greatest scourges of humanity and the challenge facing all the nations of the world soon. Thus, and to deal with it, alternatives exist; one of them consists in modifying the genes of plant and animal species, in order to increase their yield and resistance against pests and diseases.

However, a heated debate has been raging for nearly a decade, which opposes the detractors of GMOs such as consumer associations and the globalists to the multinationals and agro-industrialists, who control the market. This debate revolves around a simple question: is the use of GMOs harmless to human health, or does it constitute a risk to the environment and to biodiversity? bearing in mind more and more Start-ups are embarking on the adventure, and every day brings its share of innovations.

1. Some Essential Definitions

1.1. What is a Biotechnology

First, it should be noted that GMOs are part of a much larger field, that of Biotechnology (or Biotech in English) which is the result of a marriage between conventional biology, the science of living beings and life, and an assortment composed of various disciplines, such as chemistry, genetics, or computer science .

In fact, several definitions, more or less similar, are given to biotechnologies. In this paper, only two of them are given. One of these definitions gives the broad sense and the other is narrower and more precise:

The *Convention on Biological Diversity* (CBD) defined biotechnology in 1992 as: "*Any technological application that uses biological systems, living organisms or derivatives thereof to produce or modify products or processes for specific use*" (FAO, 2000). This general definition brings together all applications that refer to agriculture, industry and medicine.

Another definition was proposed in 2000 at a summit on biotechnology (Cartagena Protocol on Biodiversity) held in Montreal, Canada and organized under the auspices of the UN. It made a clear distinction between ancient biotechnologies and modern biotechnologies, because the definition given above, biotechnological processes were already used in Babylon and in Pharaonic Egypt (to make beer for example) thousands of years ago.

Thus, modern biotechnologies concern any application of:

- ❖ In vitro nucleic acid techniques, including DNA recombination and direct introduction of nucleic acid into cells or organelles ¹.

¹ A generic term designating the constituent elements of a living cell, such as the cell membrane, the mitochondria or the cell nucleus.

- ❖ Cell fusion of organisms that do not belong to the same taxonomic family, that overcome the natural barriers of reproductive physiology and that are not techniques used for reproduction and selection of the classical type.

Thus, modern biotechnologies encompass, among other things, both the deciphering of the genome and the development of new non-polluting bio-industrial processes, through cloning and Genetically Modified Organisms or "GMOs", which are therefore only one of the many aspects of biotechnology.

1.2. Genetically Modified Organisms (GMOs):

1.2.1. What does GMO Mean

Several definitions are proposed in the literature that deal with the subject, however, these definitions are not uniform or rather the terms used in them vary and sometimes go in opposite directions, according to the "camp that speaks about it": if they emanate from alter-globalists, hostile for the most part to GMOs, the negative aspects are highlighted in the definition and terms like pollution, hegemony or risk, are often used. If on the contrary the definition emanates from pro-GMOs, it is the positive side that is highlighted such as miracle of science, providential solution, or even panacea of humanity.

It is for this reason, that we have opted for a definition that we have considered quite neutral and that is not imbued with idealism or alarmism. This definition is the one proposed by the bodies of the European Union, and it is stated as follows: "A genetically modified organism is an organism (except for human beings) whose genetic material has been modified in a way that cannot be carried out naturally by multiplication and/or recombination" (European Commission, 2005; p 01).

The genetic modification techniques concerned include:

- ❖ Techniques of recombination of DNA, involving the formation of new nucleic combinations, through specific organisms (viruses, plasmids, etc.) and incorporated into host organisms, conferring on them properties that do not exist in their natural state, but that can be transmitted to subsequent or future generations.
- ❖ Techniques involving the incorporation into an organism of hereditary material prepared outside the body.
- ❖ Cell fusion or cell hybridization techniques, where cells that cannot fuse naturally, are forced to unite to form a new "unnatural" organism.
- ❖ However, other processes can be assimilated to techniques of genetic modification, while they are not, such as:
- ❖ Organisms produced by mutagenesis, i.e. the provocation of a mutation by a mutagenic agent such as radioactive materials and radiation (Alpha or Gamma for example) or specific chemical materials.
- ❖ Organisms obtained by the natural fusion of cells.

- ❖ In vitro fertilization, provided of course that the genetic material of the "daughter" cell, does not contain genes foreign to the species of the "mother" cells.
- ❖ Cloning or "genetic duplication", which even if it is a biotechnology, it is not a genetic modification.
- ❖ Therefore, GMOs obtained by the techniques mentioned above and better known as "transgenesis" by specialists, are modifications intended, premeditated and carried out by man. This on the one hand, and on the other hand, there are organisms in nature that practice natural and innate transgenesis, such as:
 - ❖ Retroviruses, such as the HIV virus and which are able to integrate part or all of their genome into that of the host (T4 lymphocytes in the case of HIV).
 - ❖ Plasmids, small circular and mobile DNA molecules, which can move from one cell to another and fully integrate into the host genome.
 - ❖ Reproduction between interfertile (compatible) individuals also allows the exchange of DNA between female and male chromosomes and leads to more or less pronounced forms of hermaphroditism.
 - ❖ Natural" mutations where nucleotides can² replace others.

1.2.2. Key dates of transgenesis:

Here are in brief, the main dates that marked the arrival and then the development of transgenes and GMOs:

- ❖ 1866: Johann Mendel, Austrian clergyman, sets out the first laws of the transmission of genetic traits.
- ❖ 1953: Modeling of the double helix structure of DNA, by James Watson and John Crick.
- ❖ 1972: A team from the American University of Sanford, creates a hybrid DNA combining that of a monkey and a bacterium.
- ❖ 1974: Organization in Asilomar, near San Francisco, of a conference bringing together the few specialists in transgenesis and where it was decided to stop all gene transfer in the laboratory.
- ❖ 1975: A second conference is organized in Asilomar, but this time it is the resumption of experiments banned in 1974 that is decided, with the taking of the necessary precautions and ethical rules.
- ❖ 1983: Creation in the USA of the first transgenic plant, a variety of tobacco resistant to herbicides.

² Basic links of the DNA molecule, which can contain four basic types: Adenine, Guanine, Cytosine and Thymine; their succession in a gene determines the protein for which the latter will code.

- ❖ 1994: Placing on the market of the first GMO intended for human consumption, the Mac Gregor tomato known as Flavour Saviour of long shelf life.
- ❖ 1994: Marketing in Europe of the first GMO, seeds of herbicide-resistant tobacco.

1.2.3. The Types of Genes used in Artificial Transgenesis:

Generally, 5 types of genes are used to produce GMOs.

- ❖ **Genes of interest:** they are chosen according to the goal to be achieved through the GMO. For example, we can opt for a fluorescent gene that gives the host the particularity of emitting light in the dark, or a gene that gives apples a banana taste³, or a gene that makes it possible to obtain firmer and larger tomatoes. But the gene of interest most used at the moment, and one of the most controversial, is that of tolerance to herbicides, which confer on plant organisms "useful" for humans (whether for his food, for industry ... etc.) the ability to resist broad-spectrum herbicides, such as the famous Round Up, the flagship herbicide of the American firm Monsanto, and to which we will return later.
- ❖ **Marker:** Antibiotic resistance genes are used in the production of GMOs, as markers, that is, they are made to be present in modified cells, to be able to distinguish them from those that have not been. The use of this type of genes is not the purpose but only a step and the most used genes are those that allow to develop resistance to antibiotics of the Neomycin family, the Ampicillin family and those of the Streptomycin family.
- ❖ **Male Sterility:** Other marker genes used in the production of GMOs and highly controversial because of the role they play. Thus, the male sterility gene, called Barnase, is used with another gene, Barstar (which is an inhibitor of molecules necessary for fertilization) in such a way that they prevent self-fertilization and thus make the seeds of the second generation sterile and therefore cannot be sown for a new campaign.
- ❖ **Blocking Antisense genes:** "Truncated" or "reverse-acting" genes are introduced into cells in a way that reduces the expression of normal natural genes, present in these same cells. This results in organisms that may have enormous phenotypic and/or taste differences with "normal" organisms.
- ❖ **Genes used for the creation of transgenic animals:** Which are not part of cloning, but they are no less controversial and especially in Muslim countries, because of their "interference with the divine" and where apprentice creators combine genes from sometimes very distant species (from a taxonomic point of view) to create chimeras. These experiments, because of their immorality and the repugnance they arouse, are not widely publicized and are often conducted in secret.

³ All these products actually exist, even if they are not marketed. To learn more about GMOs created in the laboratory, consult the following address: <http://terresacree.org/index5.htm#En%20vrac>

1.2.4. The Manufacture of a GMO:

The following diagram shows the main steps that lead to obtaining a GMO:

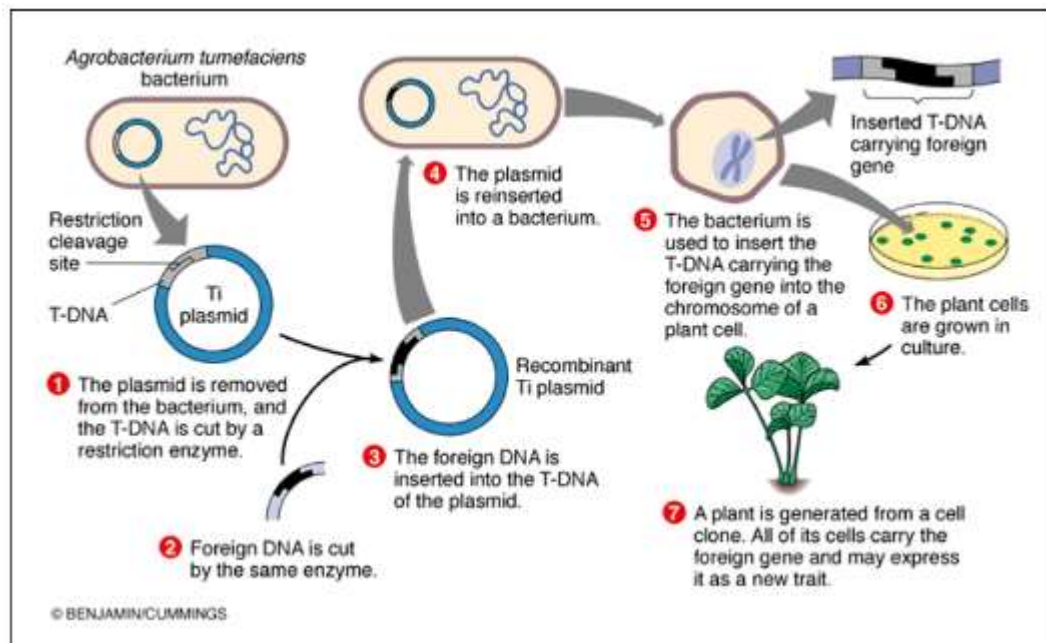


Figure 1. The essential steps for the creation of a GMO (1)

- ❖ Thus, and very briefly, a GMO is obtained in a few steps:
- ❖ A gene of interest to be introduced into a plant cell of a given species (the promoter), is incorporated into a Plasmid (or a bacterium such as *Agrobacterium tumefaciens*, also known by the initials Bt).
- ❖ Another antibiotic resistance gene is introduced into the plasmid as a "marker".
- ❖ A second labeling gene is also incorporated into the plasmid, the cloning gene. Terminator genes (the Barstar and barnase for example) are also sometimes introduced, which cause the seeds to lose all fertilizing power.
- ❖ The plasmid is in turn incorporated into a fast-multiplying bacterium with a known genome, such as *Escherichia Coli* (or E.Coli).
- ❖ After its culture with the addition of an antibiotic, the "original" bacterium will divide and give in a few hours hundreds of thousands of similar bacteria (clones) and which will all have the same modified plasmid. Unmodified bacteria, if any, will be destroyed by the antibiotic since they do not have the resistance gene.
- ❖ Plasmids are isolated, and sometimes all marker genes are eliminated, but this is not automatic. These plasmids are then transferred into plant (or animal) cells by different techniques and these same cells are cultured and after a while we have our GMO.

1.3. CRISPR-Cas9 Gene Editing Technology:

The “Clustered Regularly Interspaced Short Palindromic Repeats”, better known by the acronym "CRISPR-Cas9", is a revolutionary technology highlighted in 2012 by Emmanuelle Charpentier and Jennifer Doudna, and who received the 2020 Nobel Prize in Chemistry for this work.

In nature, the CRISPR system (discovered in the 1980s by Atsuo Nakata), uses a guide RNA (gRNA) consisting of a sequence of several nucleotides, complementary to a chosen DNA sequence, and it is originally present in bacteria which use it to degrade non-autologous DNA sequences from plasmids or viruses. It is therefore a kind of bacterial “immune” system that allows them to protect themselves against viral infections (Tremblay, 2015). Thus, CRISPR technology makes it possible to manufacture a guide RNA, which forms a complex which therefore makes it possible to cut or make targeted modifications to the genetic material of cells, in two steps. First, the complex scans the DNA double helix and stops in front of the sequence complementary to that of the guide RNA. There, the Cas9 protein cuts the DNA. Once cut, the DNA sequence of interest can be modified if necessary (Lacamp, 2020).

We can then inhibit the expression of a gene, replace it with another piece of DNA, or introduce an additional sequence. The uses of CRISPR are of enormous potential, and in particular in: the genomic improvement of plants (water resistance, nutritional profile, etc.); genomic improvement of farm animals (better yield, disease resistance, etc.); the manufacture of biofuel; gene therapy (cancer, genetic diseases, HIV, etc.); etc (Deluzarche, 2020).

2. The GMO Industry Worldwide

First of all, it should be noted that in terms of GMO production, there are producers of GMO seeds (a kind of first-degree inputs) and producers of GMOs, i.e., seeds (and not seeds) or second-generation organisms that are intended for human and/or animal consumption or industry (i.e., second-degree inputs, if they can be called that).

2.1. The Main GMO's Producers

Since the first GMO crops in 1996, the areas dedicated to them have grown considerably (multiplied by 20 since then). From 2010, the area under GMO cultivated in developing countries exceeded that in industrialized countries.(million hectares)

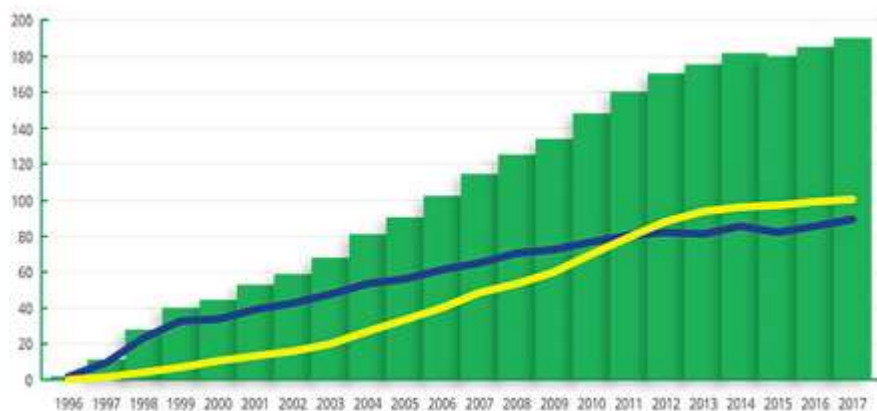


Figure 2: Evolution of GM crops worldwide, between 1996 and 2017 Linda (2018)

In 2019, 29 countries with nearly 17 million farmers were growing and producing GMOs on a large scale, including 5 industrialized countries and 24 under development. The main GMO producing countries are: the United States, Canada (for North America), Brazil and Argentina (for South America), Spain (for Europe), India (for Asia), and South Africa, Malawi and Nigeria (for Africa) (see fig.3). The USA (71.5 Mha), Brazil (52.8 Mha), Argentina (24 Mha) and India 11.2 Mha, alone

account for 83% of the world's GMO area, estimated at 190 million hectares (InfOGM, 2019), which is also equivalent to nearly 3.4% of the world's arable land. However, for African countries, a distinction must be made:

- ❖ The first group is that of GMO producers on an industrial scale : South Africa leads the way, with 2.7 million hectares cultivated in 2019.
- ❖ The second group is that of full-scale "experimental laboratories" countries: such as Ethiopia, Malawi, Nigeria, Zimbabwe or Ghana, "raw consumers of GMO seeds" where multinationals experiment in vivo their seeds.
- ❖ And finally, countries that prohibit the cultivation and marketing of GMOs, but nevertheless allow tests to be conducted in the laboratory. Potentially, Algeria is one of them.

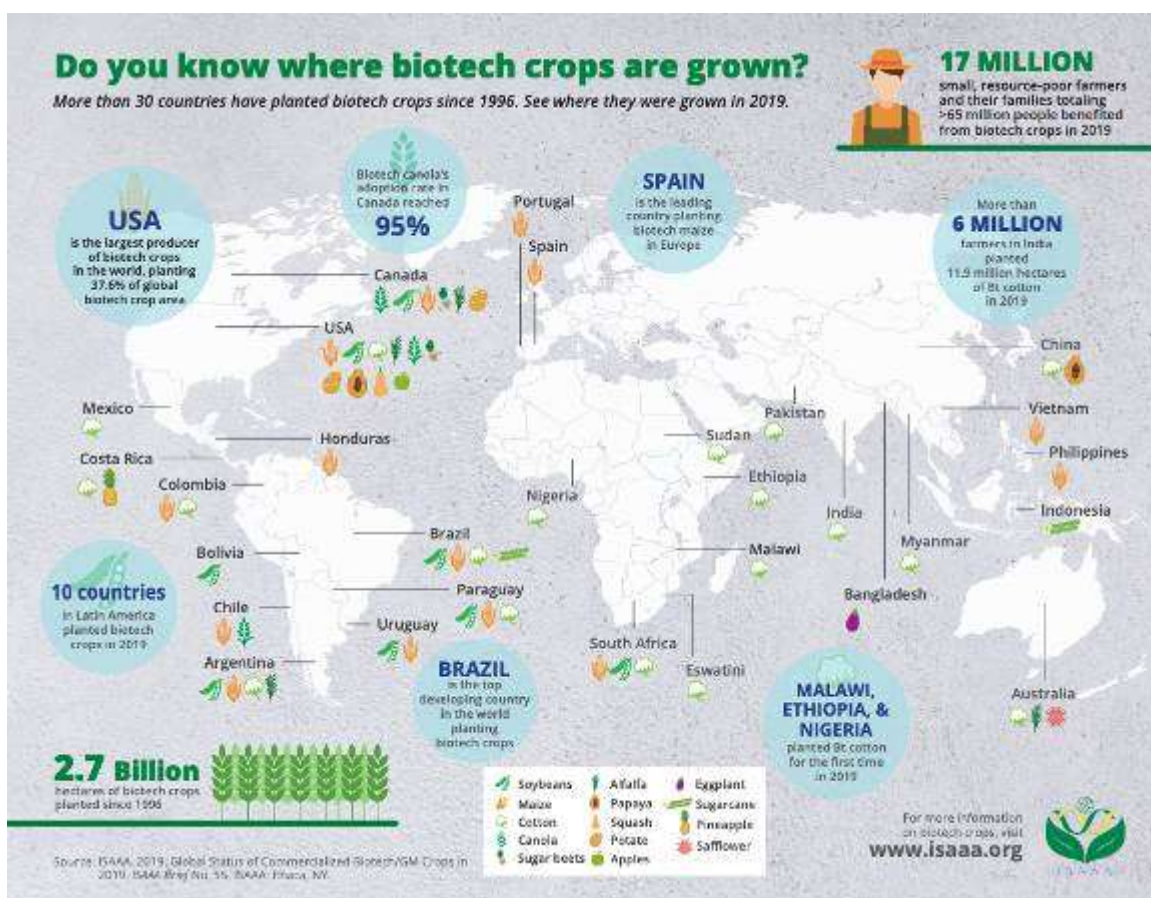


Figure 3. The main GMO's producers countries in 2018/2019 GMOs Around the World 2022

2.2. Major GMO Speculations (Crops):

Four plants alone shared 99% of the GMO surfaces in the world, these are: Soybean, Maize, Cotton and Rapeseed (Canola). Recall that these products are used in human food (Soya, Corn and Rapeseed), animal (Soybean and Corn), in the textile industry (Cotton) and even in the energy industry (biofuel from Corn; for example); in other words, it is highly strategic speculation, both in terms of its use and the profits it generates:

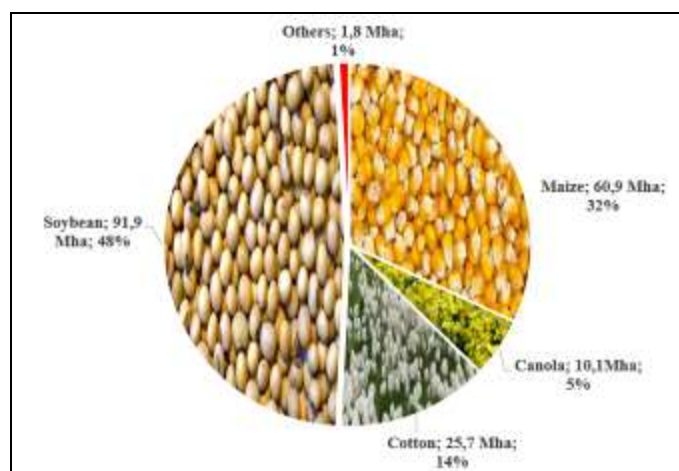


Figure 4. Area allocated to GM crops worldwide in 2019 (2)

2.3. The Main Producers of the GMO Market Worldwide:

The leading multinationals in GMOs and agrochemicals (fertilizers, pesticides, and others) such as Bayer, Corteva, Syngenta, BASF, FMC, and a few others. These companies share 56% of the seed market and 73% of the pesticide market:

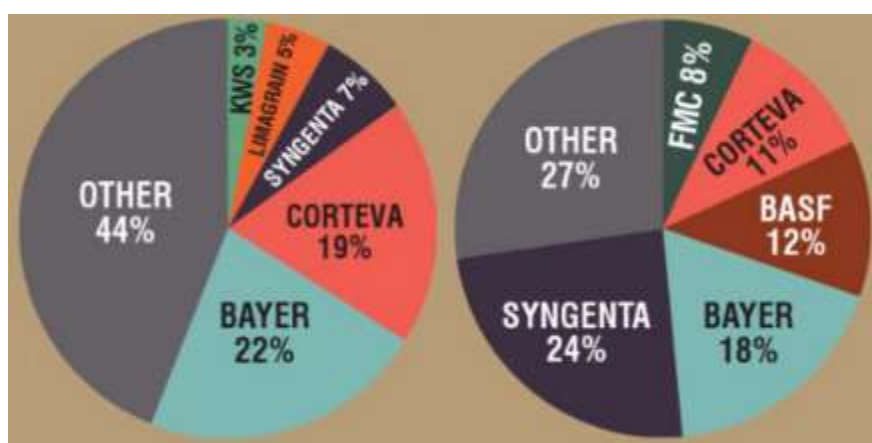


Figure 5. Market shares of the main producers in 2018/2019 of agrochemicals and seeds (GM and non-GMO) (3)

In the early 2000s, the American firm Monsanto, became detested because of its practices at the limit of ethics, the most "hated" of GMO producers, because of its unfair practices and its flagship products: Bt seeds resistant to pests, Round Ready seeds resistant to herbicides, Roun Up, the best-selling total insecticide in the world (60% market share) and the Terminorgene, which due to the controversy it aroused was never put on the market. But since then, acquisitions and mergers have accelerated in the market for GMOs and seed producers: Bayer acquired Monsanto in 2018 for \$ 63 billion; Dow and Dupont merged to become DowDupont and later created Corteva; China National Chemical Corporation (ChemChina) buys in 2016 Syngenta for \$ 43.8 billion and created Syngenta Group,. Merger and acquisition with tens of billions, which illustrate what is at stake.

3. The Opinion of both Parties:

But by the way, why all the uproar around GMOs? What are they bad at and how good are they? What are the benefits expected of them, and what are the fears they arouse?

To answer these questions, we will now present the views of pro-GMOs and anti-GMOs and start with the arguments presented by pro-GMOs in general and leading multinationals in the field, in particular:

3.1. Actual or Potential Benefits that GMOs Can Provide:

3.1.1. Dietary and Nutritional Benefits:

- ❖ GMOs can be used to correct certain nutritional deficiencies and improve the characteristics of foods. As an example, we will take a concrete case: that of Rice, which constitutes the bulk of the daily food ration of a good part of the population of East and South-East Asia. This rice is usually shelled before being consumed, and it thus loses a good part of the vitamin A, present in the shell, already that it is relatively poor. This causes serious vitamin A deficiencies to occur, especially in the youngest. These deficiencies can cause blindness and chronic diseases. To overcome this difficulty, researchers have created a new variety of transgenic rice, called golden and in which we find 3 genes of interest (two of them come from the daffodil and the third from a bacterium) that make the rice sheath "produce" more *Carotene*⁴ or Provitamin A (Roza et al., 2007).and thus allow a vitamin A intake, 25% higher compared to traditional varieties
- ❖ Other research is also being conducted to reduce the concentration of toxic substances present in certain plants (such as cyanide in Cassava) or allergens⁵ in others, such as peanuts or crustaceans. (Buchanan et al. 1997; Dubuisson et al., 2002).
- ❖ Experiments, perhaps less useful, are also taking place: a team from the University of Haifa has succeeded, for example, in producing bananas that taste like apples.

3.1.2. Agricultural and Environmental Benefits:

- ❖ High-yielding varieties of rice, wheat or maize are tested around the world by small private laboratories or by public bodies (as is the case in China). Often the GMOs obtained do not contain external genes, but "overactivated" genes or "inhibited" genes, which are responsible for the size of the stem, the number of seeds per ear, the number of feet per plant, etc. (Planchenault, 2012). These products are therefore a potential asset in the fight against undernourishment, especially in the least developed countries.
- ❖ Plant varieties are developed to produce specific and lethal enzymes for plant pests (such as the corn borer, a butterfly that ravages the stems of this plant). This makes it possible in theory to reduce the quantities of insecticides used and thus reconcile two generally antagonistic parameters: the protection of the environment and the reduction of costs and burdens borne by farmers. These transgenic varieties usually have a name followed by "Bt" and which refers to *Bacillus thuringiensis*, which acts as a gene "transporter" (Inf'OGM, 2014), so we find Bt corn, Bt soybeans, Bt rapeseed, etc., and all produce substances specific to their main pests.

⁴ Provitamins are the precursors of vitamins, i.e. Carotene goes through complex biochemical processes to give Vitamin A.

⁵ Food allergens are present in eight main families: wheat, peanuts, tree nuts, soy, shellfish, meats, milk and eggs.

- ❖ The other ecological advantage advanced by the pro-GMOs is that of herbicides: Indeed, some weeds invade the fields of crops of interest and cause yield drops of up to 30%, or even more, in response to which, farmers use herbicides in several varieties and several times a year. Companies such as Monsanto have developed total herbicides, such as the Round Up that we have already mentioned, which eliminates all plants, good or bad, except those that carry the Round Ready gene, which gives the carrier and thanks to inhibitory substances, the ability to survive the effects of this formidable herbicide (Schluter, 2015). This also contributes in theory to environmental protection: fewer herbicides are used, fewer charges to bear and less pollution for soils and groundwater.
- ❖ As far as animal genetic engineering is concerned, some researchers are working to create breeds of farm animals with improved characteristics and high productivity : cows that give more milk, short-cycle and fast-growing broilers or sheep that supply and more wool, are some of many hopes placed in research into transgenic animals. However, the manipulation of animal cells is much more delicate than for plant cells and requires more investment and above all it is more controversial.
- ❖ One of the most interesting uses for humans and which will have the most positive repercussions on the environment, is the creation of organisms tolerant to abiotic stresses, that is to say to physical (and non-living) factors that can lower yields or compare the cultivation of certain plant species, or even make any cultivation impossible :d S GMOs resistant to salt and can be grown on the salty lands of the Sahel or tolerant of Aluminum, responsible for soil acidity in several regions of the world, or giving plants xerophylable properties, i.e. drought-resistant; this will take agriculture a giant step forward (Jewell et al. 2010).

3.1.3. Medical and Therapeutic Benefits:

- ❖ Biotechnology opens up enormous prospects for medicine, but let us stick to GMOs: Researchers are trying to incorporate vaccines into widely consumed fruits or vegetables, and we are already talking about the banana vaccine, which would contain the vaccine of hepatitis, SARS or poliomyelitis and which could be produced at a lower cost and distributed to poor populations who have difficulty accessing traditional health facilities (Lucht, 2005).
- ❖ Some pharmaceutical companies are seeking to develop organizations that would allow them to produce in quantity the substances necessary for the manufacture of certain drugs (Houdebine, 2001). This will obviously contribute to the preservation of biodiversity and especially in tropical forests, which suffer from looting organized by the drug giants ⁶.
- ❖ Man himself is in the process of becoming a GMO in the true sense of the word, insofar as gene therapy consists in introducing modified cells into the laboratory in order to correct physiological, immune or other defects.

These are some actual or potential benefits offered by biotechnology in general and GMOs in the field. Nevertheless, all this is questioned by the detractors of GMOs, who ultimately see it as nothing, but the dreams of a humanity harassed and driven to despair by problems that it cannot cope with traditional means.

⁶40% of the drugs produced are from natural substances.

3.2. The Criticisms Made of GMOs and the Risks Associated with them: 3.2.1. Multinationals with Sneaky Practices and a more than Dubious Past:

GMO multinationals are often criticized for their business strategies based essentially on:

- ❖ Concomitance: to the extent that some of them sell seeds and additional inputs without which the seeds cannot germinate or cannot use the gene of interest incorporated into them. *Monsanto*, for example, sells its de-rant *Round Up*, but implicitly forces farmers to also buy seeds that tolerate it. There is also the example of the *Traitor* genes incorporated into GMOs produced by *Syngenta*, which prevent plants from developing (they remain in a latent state) and can only flourish if they are sprayed with a special product sold by the same company.
- ❖ These same *Traitor* genes and others too, have an inhibitory action of the gene of interest and make this gene dilute and the plant thus loses in the following generations, its character of interest, thus forcing farmers to buy the seeds every year. This annihilates one of the major characteristics of agriculture: that of the reproducibility and regeneration of a first-rate input: seeds. In normal agriculture, 80% of the seeds of the current year come from the previous year; So in addition to the food and technological dependence suffered by many Third World economies, the specter of "biotechnological dependence" looms on the horizon.
- ❖ The prices at which these seeds are transferred are generally 2 to 3 times higher than those of traditional seeds. The farmers most affected by this exorbitance are those in poor countries: the promises of less tedious work, higher yields, and lower costs, push these farmers to buy seeds at a high price, even if it means going into debt... But when the time comes for the harvest, many of them commit suicide or declare fail, because often the expectations are not at the appointment.

One of the other "disturbing" aspects of these same multinationals is certainly not related to GMOs, but rather to the inglorious antecedents of these companies:

- ❖ *Monsanto*, (before being acquired by *Bayer*) none other than the inventor and seller of the *Agent Orange defoliant*, commonly known as "*Agent Orange*"; an ultra-powerful herbicide used by the U.S. Military during the Vietnam War to destroy tropical vegetation and hinder the movement of the Viet Cong.
- ❖ *Dupont*, another giant among GMO producers, processes and enriches plutonium used for military purposes, manufactures *Chlorofluorocarbon* (CFC), used as a refrigerant and highly polluting power and one of its subsidiaries produce leaded gasoline.
- ❖ *Dow Chemicals*, is a former manufacturer of Napalm, the gelled essence used in the deadliest conflicts that humanity has known. This product is embedded in clothing and sticks to the skin to cause 3rd degree burns.

What credibility for these companies that declare themselves for the preservation of the environment, altruistic of the first rank and working for the well-being of humanity

- ❖ Trampled bioethics is one of the other reproaches made to GMO multinationals. Indeed, playing sorcerer's apprentice risks turning against these apprentice-creators? Does man have the right to interfere with the laws of nature and the living, moreover, to upset mechanisms and rules that have taken millions of years to establish?... In view of what biotechnologists do, these considerations are the last of their worries, and many have become anti-GMO because of these

ethical questions and in particular the *Creationists*⁷ many of whom judge some creations from biotechnology, as being a direct and intolerable interference with the divine, and some thinkers who believe that Biotech and GMO's promote *Eugenism*⁸ And the myth of the perfect man (Nos libertés, 2008), or even the perfect soldier, and which recall Hitler and other supremacists and their foolish reign of a pure and perfect superior race.

- ❖ All this without forgetting the patents affixed to GMOs or "patenting of the living" (Orès and al, 2015), and woe to the one who deviates from the rule and sows seeds without authorization. But there is even more serious: GMO multinationals do what they call "bioprospecting" and send experts on expeditions to the four corners of the globe to find genes containing a particular power; but the problem is that this "biopiracy" as the natives of the regions from which these genes are collected call it, is done without their approval... After all, they do not own them, but why appropriate them when these same genes are the real added value of GMOs? False paradox but real issue

3.2.2. Health Risks:

- ❖ GMOs can help reduce the concentration of allergens, but can also create others: the pioneering company of GMO seeds, created for example a few years ago, a soybean richer in methionine, which is a necessary amino acid (therefore not synthesized by the human body) and incorporating DNA sequences from Brazil nuts. Unfortunately for Pioneer, laboratory tests have shown that the serum of people allergic to Brazil nuts, also reacts with transgenic soy, and this may therefore cause allergies, following which this soy has been withdrawn from the market.
- ❖ The presence of antibiotic resistance markers is also a cause of concern for anti-GMOs: the ingestion of GMOs would risk in the long term to make their genes cross the species barrier or end up in the genome of pathogenic bacteria, which would give them resistance to the antibiotics in question⁹.
- ❖ There are also doubts about the safety of GMOs, once inside the human or animal organism: won't their new properties create unexpected and harmful ones? will they not disturb the digestive system and the microbial flora in it? So many questions and very few answers...
- ❖ Finally, several anti-GMO organizations (Green peace and *Via Campesina*, among others) refer to studies conducted mainly in Africa, India and Southeast Asia, to counterarguments on the agricultural benefits of GMOs : neither Bt maize nor Bt rapeseed allow an increase in yields. In addition, they rely on the report of the US Department of Agriculture of May 1999, which cites the work of agronomists from the University of Iowa and Arkansas, and according to which the yields of transgenic rapeseed and soybeans are just over 1%, compared to traditional non-GMO varieties, and the doses of pesticides used in transgenic corn fields are just 1% lower than in varieties. Traditional.

⁷ Creationism is the belief that the universe and living organisms originate from specific acts of divine creation.

⁸Developed largely by Sir Francis Galton as a method of improving the human race. It consist to the study of how to arrange reproduction within a human population to increase the occurrence of heritable characteristics regarded as desirable.,.

⁹Fears also shared by the WHO, and whose surveys reveal that more than 10,000 people die each year because of the resistance of germs to antibiotics.

3.2.3. Ecological Risks

The impact of GMOs on the environment is currently the favorite workhorse of anti-GMOs, they take advantage of the fears raised by global warming to denounce practices that can cause irreversible and unparalleled damage to the ecosystem. These environmental effects are grouped into two categories: direct effects and unintended effects.

• Direct Effects

The transfer of genes of interest to other species related or not to the GMO. In the first case "gene flow" as it is called, causes a cross between GMO plants and others not genetically modified (natural) and will cause "gene pollution" (FAO, 2003), as reported by the journal *Nature* and where researchers estimated after long work in Oaxaca, Mexico, that 10% of all maize plants have been contaminated with transgenic maize genes (Quist and Chapela, 2001). It is also possible that these genes are found in harmful plants, which would provide them with resistance to herbicides and pests and thus give them an "evolutionary advantage" over other plant species occupying the same ecological niches and be the cause of their disappearance.

- ❖ As for the transition of genes to "non-neighboring" species, it would be catastrophic for the environment and new plant species or insects with unknown characteristics could emerge. Species with unpredictable behavior, since unknown and new.
- ❖ Increased use of herbicides as a consequence of farmers who, in possession of resistant GMOs, could increase doses and thus lead to increased pollution of the soil and groundwater.
- ❖ Risk of disappearance of notions of species, insofar as transgenesis can bypass the species barrier (which normally prevents a cow from crossing with a camel for example) and would theoretically make it possible to stir the genes of organisms that would have the characteristics of plant X, fish Y and insect Z, all assembled into one being. How to classify this organism then? in which kingdom should they be placed? Problems that will soon arise at the rate things are going.
- ❖ The loss of the specificity of the agricultural world is greatly feared by confederations and peasant associations, who fear the day when cereals, fruits and vegetables are, through genetic engineering, produced in factories and when there will no longer be any distinction between worker and farmer.

• Indirect Effects

Other environmental effects are also feared, indirect or unintentional effects resulting from changes in cultivation practices, which occurred as a result of the use of GMOs, already that conventional insecticides and herbicides have been responsible in the past for the destruction of the habitats of field birds and insects. However, scientists differ as to the overall positive or negative impact of these changes on the environment.

3.3. The Hypocrisy of Each Other:

A simple look at the arguments presented by the antagonists, shows how sensitive the issue of GMOs is and the enormity of the stakes of a merciless joust, where all blows are allowed and where no one is ever entirely right. Here are a few examples:

- ❖ The GMO multinationals, the first defenders of the products they create, take advantage of the misery of the Third World and the hunger that plagues it to tilt consumer opinion in their favor. Where is this high-yielding wheat? that tomato that weighs double its ordinary weight? the analysis

of the structure of the products sold by some of these firms proves that what matters to them is not the hunger of Africa or the blind children of Asia, but to reap the most profits.

- ❖ As for the anti-GMOs, even if their intentions remain laudable, they too do not hesitate to use even more fallacious arguments: their refusal of globalization pronated by the WTO, pushes them to reject everything that emanates from it or is related to it, globalization also adored by GMO multinationals.
- ❖ Moreover, and so far, in countries where GMOs are grown, there has been no conclusive indication of damage to the environment (apart from a few cases of contamination of non-GMO fields) or to the health of consumers. Maybe it's for lack of hindsight, but we shouldn't be too alarmist either.
- ❖ And then there is not one GMO, but GMOs that differ a lot from each other and anti-GMOs, and if each of them were to be tested in the long term, they would lose all their interest in the eyes of multinationals, because these tests are usually conducted for a period that exceeds the commercial life of GMOs. Investment would decline and firms would be reluctant to enter a moribund market with low incomes.
- ❖ The scientific community agrees that the use of Bt varieties should in principle reduce the use of insecticides, as has already been observed in South Africa for cotton crops, in Australia, China and Mexico for rice and maize; which is beneficial for the environment in general (less pollution) and biodiversity in particular (fewer broad-spectrum insecticides).
- ❖ Also, reducing the use of insecticides with GMOs contributes to improving the health of agricultural workers, and this has been demonstrated in China by Pray et al (2000) and in South Africa by Bennett et al (2003).
- ❖ As for the risks associated with marker genes, the International Wheat and Maize Center, better known by its Spanish abbreviation CIMMYT, has, for example, succeeded in developing techniques that allow the production of GMOs without the use of antibiotic resistance genes.
- ❖ As for the Terminator or Traitor gene, its use is part of the mercantilist strategy of GMO multinationals, and we can do without the usefulness of GMOs being affected. So, in the end, it's not the fault of the GMO itself, but of its designer.
- ❖ With regard to the fall of the species barrier or the dreaded gene flow, it must be admitted that laboratory conditions do not always prevail in the field.
- ❖ On the one hand, the transfer of a gene from one GMO plant to another plant is very unlikely for distant species (genetically speaking), as for intraspecies transfer, the neighborhood must be both genetic and spatial (proximity between GMO fields and others with non-genetically modified plants).

And for the most cultivated GMO species, the following matrix, proposed by FAO ecologists, shows the degree of risk of transfer of modified genes to other species

It is easy to see that wheat and rice, which make up the bulk of the daily food ration of the populations of Asia and Africa, have low probabilities of crossing with genetically related species, even if they are "spatially".

		Nearby compatible wild weed plants	
		No	Yes
Cross-fertilization potential	Weak	Soybean	Rice Sorghum Wheat
	Strong	Cotton Maize	Sunflower Brassica Carrot Squash Radish Poplar

Figure 7. Matrix of gene transfer probabilities for selected human-cultivated plant species (FAO 2003.-2004)

4. Some Success Stories of Promising Biotech/GMO Start-up:

So, many of the criticisms made of GMOs, is due to the fact that they are developed and marketed by large companies with dubious practices and wanting to impose their will to have control over the market of health and human food, fears also confirmed by the race for vaccines against COVID 19 ...

However, several other companies are also evolving on the GMO market, Start-ups may not be entirely altruistic, but which can still constitute a consensus between anti- and pro-GMOs: To make humanity benefit from the benefits of GMOs and not to possess sufficient market power to hold hostage a humanity already in distress.

In the following, we will present some of these innovative start-ups that mostly use the CRISPR technology mentioned above.

4.1. PLANTeDIT, increasing the Worldwide Food Supply using CRISPR:

Founded in 2017 in Cork (Ireland) by Chidananda Nagamangala Kanchiswamy. It utilizes next generation genome editing technology to produce DNA-free, regulatory free, consumer oriented and sustainable genome edited crops and cost-effective biopharmaceuticals (Plantedit, 2017).

The company focuses on creating modified plants that contain no foreign genetic material in an effort to meet the ever-increasing demand for "design" crops while bypassing both the general aversion to ingesting non-plant DNA or RNA and regulatory barriers around traditional "GMOs."

In the past, food companies used hydrogenated oils (trans fats) to keep food shelf-stable and preserve flavor. When companies had to stop using trans fats, they switched to high oleic oils or palm kernel oil to make their food last longer for customers (Plantedit, 2018).

So, among plantedit's flagship projects, the creation of a CRISPR-Cas9-modified soybean sn with a high oil content named SOLive. This oil is similar to olive oil but can be used to fry food products at higher temperatures and store fried products for longer periods of time. The company is currently

developing improved fruit products and turfgrass in hopes of generating next-generation sustainable food (Prabhune, 2020).

4.2. Pairwise, Development of New Varieties of Crops:

Pairwise, founded in 2018 in Durham (UK) by Keith Joung, Feng Zheng and David Liu, is a British pioneering food start-up, committed to helping people live healthier, fuller lives. It uses CRISPR technology, deep crop science expertise and cutting-edge data techniques to create new cultures and modify existing ones. The goal is also to help farmers by providing them with new crop varieties that require fewer resources to grow (Pairwise, 2020), including water resources and fertilizers. As a result, the products that this Start-Up expects to develop will contribute to the preservation of the environment (reduction of the use of fertilizers) and will be an asset for countries suffering from water stress (or drought).

Pr elsewhere, because of the intellectual property brought by the founders of the company, this company is technologically strong. They have licenses for basic publishing technology from Harvard University thanks to the research of their founders. By leveraging this technology, they hope to solve the big problems faced by the agricultural industry (Prabhune, 2020).

4.3. Inari, the Producer of "Personal" Seeds:

"At Inari, we're working to transform the global food system: From sustaining population growth, to building the population's health. From minimizing environmental damage impact, to creating a positive change for the planet. And from exploiting those who feed us, to building wealth for those rural communities" (Inari, 2019)... these are the objectives of this Start-up founded in 2016 by George and Steve Jacobsen Church in Cambridge, Massachusetts (USA). It therefore produces "tailor-made" seeds through the use of CRISPR9 technology, that is, by managing the expression of specific genes in a plant and promoting optimized traits so that it grows best under specific conditions. These "personalized" seeds can therefore be adapted to particular edaphic conditions (humidity, temperature and soil), such as seeds likely to germinate on saline soils or in regions where evapotranspiration is important. Thus, among Inari's objectives, increasing the yields of corn and soybeans by 20%, reducing the water consumption needed for corn by 40%, and also, reducing the nitrogen (fertilizers) needed for corn by 40%.

4.4. Solar Food Produce Food from almost Nothing

Based in Helsinki (Finland) and established in 2017, a spinoff from a "VTT Technical Research Center of Finland" and "Lappeenranta University of Technology" research program. It aspires to produce food using only water, air, electricity and bacteria. The result is *Soleine*, a natural protein that can be added to any meal or used as an alternative to meat (Solarfood, 2019).

In 2021, the company submitted an application for approval of Solein in the European Union as a novel food. In 2022, Solar Foods plans to complete the construction of its manufacturing facility, which will have the capacity to produce up to 50 million meals per year, and launch its product globally (McCafferty, 2019).

The company is also working with the European Space Agency to test Solein's production in space to reduce waste and weight in long-range space missions (Solarfood, 2021).

4.5. *Viridos the Producer of Green Fuels:*

This Startup and even if it is not specialized, like those mentioned above, in the production of food, deserves to be mentioned: Formerly called Synthetic Genomics, it was founded in 2005 by *Juan Enriquez* and *David C. Kiernan*, among others, and is based in San Diego (USA). Viridos uses CRISPR technology to modify microalgae genes to produce low-carbon, renewable heavy transportation fuel for trucks and aircraft, thereby reducing carbon emissions by 70% (Viridos, 2021). One goal may be surreal, but one that is nevertheless justified by the urgency of the situation: global energy consumption will increase by more than 50% by 2050 (Virios, 2021), an even more intense and dangerous global warming for the future of humanity.

Conclusion:

The fears expressed by anti-GMOs are sometimes unfounded and exaggerated and benefit from a wide media echo: greenhouse effect and global warming have put everything related to the environment back in fashion and alter-globalists and "ecolos" have become (perhaps out of nostalgia for the 60s and 70s) the hippies of the 21st century.

As for the GMO multinationals, they mostly have a capitalist and mercantilist reasoning and their behavior is sometimes unscrupulous and the opposite of any altruism, otherwise, how to take advantage of the famine in Africa and put up images of children with sagging bellies (not full of food, but suffering from *Kwashiorkor*) just to rally public opinion to the cause of GMOs and also to achieve higher turnover.

To summarize, it can be said that: anti-GMOs use bad arguments for good reasons, and pro-GMOs use good arguments for the wrong reasons and this should not be the inquisitorial trial of GMOs, but that of the multinationals that produce them and whose practices are sometimes revolting. But let us still agree that the absence of proven misdeeds in the present time does not mean that there will not be in the future, so caution is required, but caution must not mean stagnation or rejection.

Moreover, the few examples of start-ups we have mentioned, these companies built and focused on innovation, are far from claiming to "govern the world" or impose unbridled capitalism on the rest of the world... Certainly, they are guided and like any other company by profit, but not only, because they show a real will to provide solutions to the problems of humanity and in particular those related to its food.

To conclude, let us take up the words of Jacques Pagès: "One thing is certain: we cannot say *GMOs*, but *such GMOs used in such a condition*"

References

- Anonymous. 2008.** OGM : un projet eugéniste, publication du Site du mouvement « Nos Libertés », Aout 2008. [Réveillons nous.free.fr/doc/OGMUnProjetEugeniste.pdf]
- Buchanan B. and al. 1997.** Thioredoxin-linked mitigation of allergic responses to wheat. Proceedings of the National Academy of Sciences USA, 94, 5372–5377.
- Commission Européenne. 2005.** Questions et réponses sur la réglementation des OGM dans l'Union européenne, Memo 05-104, Bruxelles, le 22 Mars 2005. [europa.eu/rapid/press-release_MEMO-05-104_fr.pdf]

- Deluzarche C. 2020.** CRISPR : qu'est-ce que c'est?. Futura Aanté, Octobre 2020. [<https://www.futura-sciences.com/sante/definitions/genetique-crispr-14962/>]
- Dubuisson C. et al. 2002.** Allergies alimentaires : Etat des lieux et propositions d'orientations, Rapport de l'Agence Française de Sécurité Sanitaire des Aliments, Janvier 2002. [fulltext.bdsp.ehesp.fr/Afssa/Rapports/2002/Allergies_alimentaires.pdf]
- ETC Group 2013.** Gene Giants Seek Philanthropopoly, ETC Group, 2013 [www.etcgroup.org/sites/www.etcgroup.org/files/ETCNR_CharityCartel_07March2013.pdf]
- FAO. 2000.** La FAO souligne le potentiel des biotechnologies mais recommande la prudence, Communiqué de presse 00/17 [http://www.fao.org/WAICENT/OIS/PRESS_NE/PRESSFRE/2000/prfr0017.htm]
- FAO. 2003.** Glossaire sur les ressources génétiques forestières (Version française), Département des forêts, FAO, Septembre 2003 [[ufro-archive.boku.ac.at/silvavoc/glossary/fr.pdf](http://fro.archive.boku.ac.at/silvavoc/glossary/fr.pdf)]
- FAO. 2004.** La situation Mondiales de l'Alimentation et de l'Agriculture 2003-2004, Collection FAO Agriculture n°35 [[ftp://ftp.fao.org/docrep/fao/006/y5160f/y5160f.pdf](http://ftp.fao.org/docrep/fao/006/y5160f/y5160f.pdf)]
- Houdebine L.M. 2001.** La production de médicaments par les OGM, Conférence donnée à Agropolis-Museum [museum.agropolis.fr/pages/savoirs/transgenese/transgenese.pdf]
- Inf'OGM. 2014.** Qu'est-ce qu'une plante Bt, Juillet 2014 [agriculture.gouv.fr/telecharger/62569?token=c043de062d1e1ae5b5ab51a747318467]
- ISAAA. 2016.** Global Status of Commercialized GM/Biotech Crops: 2016 [www.isaaa.org/resources/publications/briefs/52/download/isaaa-brief-52-2016.pdf]
- Jewell M.C and al. 2010.** Transgenic plants for abiotic stress resistance, In Transgenic Crop Plants, Springer editions, Volume 2, 2010.
- Lacamp I. 2020.** Prix Nobel de chimie 2020 : à quoi sert la technologie d'édition génomique CRISPR-Cas9, Sciences et Avenir Online, 07.10.2020. [https://www.sciencesetavenir.fr/fondamental/biologie-cellulaire/a-quoi-sert-la-technologie-d-edition-genomique-crispr-cas9_141256]
- Lucht J. 2005.** Des tomates OGM servent de vaccin contre le SRAS, In Point, n°44, Juin 2005 [fr.scienceindustries.ch/_file/17243/point-2005-06-44-f.pdf]
- McCafferty H. 2019.** Solein : un aliment créé à partir d'eau, air et électricité [www.finedininglovers.fr/article/solein-un-aliment-cree-partir-deau-air-et-electricite]
- Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (2016),** Informations générales sur les OGM [http://www.ogm.gouv.qc.ca/ogm_chiffres/principales_cultures.html]
- Orès B. et al. 2015.** La brevetabilité du vivant, Document de "Conseils en Propriété Industrielle", Décembre 2015 [http://www.cncpi.fr/fckupload/File/ESPACE%20PRESSE%20texte/2015_12/CNCPI_Article%20La%20brevetabilite%20du%20vivant_BOres%20-%20FParis%20-%20LVial.pdf]
- Planchenault D. 2012.** Rapport sur les biotechnologies et les nouvelles variétés végétales, Ministère de l'agriculture, de l'alimentation, de la pêche, de la ruralité et de l'aménagement du territoire, France, Février 2012 [agriculture.gouv.fr/telecharger/62569?token=c043de062d1e1ae5b5ab51a747318467]
- Prabhune M. 2020.** Top CRISPR Startup Companies Changing the Future of Biotech and Medicine. [<https://www.synthego.com/blog/crispr-startup-companies>]

- Quist D. and Chapela I.** 2001. Transgenic DNA introgressed into traditional maize landraces in Oaxaca, Mexico. In la revue *Nature*, v.414 du 29 novembre 2001.
- Rozan A. et al.** 2007. Acceptabilité des consommateurs face à un OGM de seconde génération : le riz doré, *Revue d'économie politique* 2007/5 (Vol. 117), p. 843-852. [DOI 10.3917/redp.175.0843]
- Schulter D.C.** 2015. Contested Safety : Monsanto's "Round Ready" agricultural assemblage versus counter discourses of Roundup Risk, Thesis of Master of Arts, Arizona State University, USA, May 2015 [repository.asu.edu/attachments/ 150819/content/Schluter_ asu_0010N_15102.pdf]
- Tremblay J.P.** 2015. CRISPR, un système qui permet de corriger ou de modifier l'expression de gènes responsables de maladies héréditaires, In *Med Sci (Paris)*. Volume 31, Number 11, Novembre 2015. [https://doi.org/10.1051/medsci/20153111016]

Webography:

- Sources d'information sur les organismes génétiquement modifiés- OGM et Chiffres - www.ogm.gouv.qc.ca/ogm_chiffres/principaux_producteurs.html. (Accessed on December 15th, 2021)
- http://jlbazin.free.fr/multinationale_ogm.htm (Accessed on January 27th, 2022)
- Ces OGM existent déjà: La plupart ont échappé aux medias! <http://terresacree.org/index5.htm>. (Accessed on December 03rd, 2021)
- GMOs Around the World 2022. <https://gmoanswers.com/gmos-around-world>. (Accessed on January 14th)
- Linda Poppenheimer (2018), Green Groundswell. Home of the Unlikely Environmentalist <https://greengroundswell.com/gmos-and-bioengineered-food-what-is-it/2018/07/16/>. (Accessed on December 13th, 2021)
- INARI. If you wanted to change tomorrow, what would you do today? <https://inari.com/our-expertise>. (Accessed on January 29th, 2022)
- SEEDESIGN Platform in Corn, Soy and Wheat. Satisfying demand Enriching the environment. <https://inari.com/seeddesign>. (Accessed on January 29th, 2022)
- Plantedit. DNA-FREE GENNE-Editing. <https://plantedit.com/index.php/whoweare/>. (Accessed on January 29th, 2022)
- Digesting the future. <https://solarfoods.fi/blog/>. (Accessed on January 29th, 2022)
- Inf.OMG. Veille citoyenne d'information sur les OGM et semences. <https://www.infogm.org/-Qui-cultive-des-OGM-dans-les-monde-Et-ou->. (Accessed on January 27th, 2022)
- Viridos. (Formerly Synthetic Genomics, Inc), is a California based biotechnology Company. <https://www.viridos.com/about-us/>. (Accessed on January 29th, 2022)
- Bouakba Amel 2005. Ya-t-il des OGM dans nos assiettes en Algérie? *La tribune- online.com*. www.algerie-dz.com/article2060.html. (Accessed on December 03rd, 2021)
- OGM et Consommateur. www.creaweb.fr/bv/ogm/presentation2.html. (Accessed on December 08th, 2021)
- Ibr/sd (AFPF), Made for minds. Top Stories. Global GMO cultivation dipped in 2015. www.dw.com/en/global-gmo-cultivation-dipped-in-2015/a-19190800. (Accessed on January 04th, 2022)
- Futura Santé. Dossier-OGM: un tour d'horizon complet. Qu'est ce qu'un OGM : Organisme Génétiquement Modifié? www.futura-sciences.com/fr/comprendre/dossiers/doc/t/genetique/d/ogm-un-tour-dhorizon-anscomplet_223/c3/221/p2/. (Accessed on December 08th, 2021)

- Greenpeace. www.greenpeace.org/france/campaigns/ogm. (Accessed on December 15th, 2021)
- Noisette Christophe. 2003. Algérie- Atelier sur la participation du public. Inf'OGM. Veille citoyenne d'informations sur les OGM et les semences. www.infogm.org/ALGERIE-Atelier-sur-la.html. (Accessed on December 08th, 2021)
- www.jeuneafrique.com/jeune_afrique/article_jeune_afrique.asp?art_cle=LIN25066ogmafsniaci0 (Accessed on December 08th, 2021)
- www.journal-la-mee-2.info/article.php3?id_article=1336 (Accessed on December 13th, 2021)
- Environnement et lute contre les changements climatiques. Québec.
www.mddep.gouv.qc.ca/biodiversite/biosecurite/cartagena.htm#cartagena. (Accessed on December 20th, 2021)
- FAO "La situation Mondiales de l'Alimentation el de l'Agriculture 2003-2004»
- (1) Geneticcally Modified organisms. https://sphweb.bumc.bu.edu/otlt/mph-modules/ph/gmos/gmos_print.html. (Accessed on December 03rd, 2021)
- Vigilance OGM. Impact sur l'agriculture. www.vigilanceogm.org/les-risques/agricoles. (Accessed on January 17th, 2022)
- (2) By the authors (data source: <https://www.isaaa.org/resources/publications/pocketk/16/>)
- (3) <https://cbn.ca/gmos/issues/corporate-control/>