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Research Panorama on the Second Green Revolution in the World and Colombia

Panorama investigativo sobre la segunda revolución verde en el mundo y en Colombia

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Abstract

The second Green Revolution is understood as the development of transgenic varieties, using tools such as genetic engineering and molecular biology applied to the DNA molecule. The product of the second Green Revolution corresponds to genetically modified organisms (GMOs) developed from inter-species cross manipulation and genetic information of some species of interest. The second Green Revolution was established as a strategy to help ensure food security, an increasingly growing population, and demanding of resources, to optimize crop productivity improving or introducing specific characteristics such as resistance to insects and herbicide tolerance to allow GMOs to be more tolerant of natural aggression. The debate on this revolution is maintained, sharpening and raising many interests due to its transversal aspects and impact on social, scientific, economic, political, and ecological issues. This paper aims to review the history, development, and applications of the second Green Revolution framed within the advantages and disadvantages of the environmental components that interact on the soil. Due to the impact of the techniques used by the second Green Revolution and the various complex interactions among different environmental components, this paper provides a panoramic description open to discussion and research in soil science and landscape ecology, leading the precise determination of the conditions generated in the natural and human environment. To conclude, a SWOT analysis is made available of transgenesis in environmental components.

Keywords*:* Biotechnology, Biodiversity, Soil Science, Landscape Ecology, Green Revolution, Transgenesis, Genetically Modified Organisms

Resumen

La segunda revolución verde se entiende como el desarrollo de variedades transgénicas utilizando herramientas como la ingeniería genética y la biología molecular aplicadas a la molécula de ADN. El producto de la segunda revolución verde son los Organismos Genéticamente Modificados (OGM) desarrollados a partir de la manipulación y cruce interespecífico de la información genética de algunas especies de interés. La segunda revolución verde se estableció como una estrategia para ayudar a garantizar la seguridad alimentaria de una población cada vez más creciente y demandante de recursos, teniendo como propósito optimizar la productividad de los cultivos mejorando o introduciendo características específicas como la resistencia a insectos y tolerancia a herbicidas que permitan a los OGM ser más tolerantes a las agresiones del medio natural. El debate sobre esta revolución se mantiene, se agudiza y

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suscita muchos intereses debido a su transversalidad e impacto en aspectos de orden social, científico, económico, político y ecológico. En este documento se pretende revisar los antecedentes, desarrollo y aplicaciones de la segunda revolución verde enmarcados en las ventajas y desventajas que presenta sobre los componentes del medio ambiente que interactúan en el suelo. Debido a las repercusiones de las técnicas usadas por la segunda revolución verde y a las diversas y complejas interacciones entre los diferentes componentes ambientales, en este escrito se hace una descripción panorámica abierta a la discusión e investigación en la edafología y la ecología del paisaje, que conduzcan a la determinación precisa de las afecciones generadas en el medio ambiente natural y humano. De manera concluyente se encuentra un análisis DOFA de la transgénesis en los componentes ambientales.

Palabras clave: Biotecnología, Biodiversidad, Edafología, Ecología del Paisaje, Revolución verde, Transgénesis, Organismos genéticamente modificados

1. Introduction

Soil constitutes the support to life and upon it a series of activities are developed, which according to human thought tend to improve the quality of its subsistence; however, how successful could the different practices and scientific progress be to integrally satisfy said subsistence. The present review[1] constructs a national and international panorama of one of those activities that can already be reflecting natural alterations on the edaphodiversity and its ecological relationships. In the search for alternatives to diminish the effects of the growth of the global population and to guarantee food security for said population, a new proposal was generated during the course of the Second World War called "Green Revolution", this mode of agricultural production was created in industrialized societies and consisted in maximizing races and seeds through the so-called technological packages, which included irrigation, mechanization, chemical fertilizers, pesticides, herbicides, and concentrated foods. With this idea of maximizing the seed (in essence, the proposal by Norman Bourlaug for which he received the Nobel Peace Prize in 1970), the highest global production was obtained: surface cultivated per inhabitant dropped globally from one half to a quarter hectare between 1950 and 1995. Between 1975 and 1995, in developed nations, production increased notably: 78% in cereals, 113% in fishing, 127% in beef, 331% in eggs, and 280% in poultry (FAO, 1998) [1].

The Green Revolution, or any other strategy to increase food production to relieve world hunger, depends on cultural, economic, and political regulations. One of the proposals considered to improve the quality of life on the planet was to consider another option within what could be denominated a *second Green Revolution*. According to the delegates to the World Food Summit, to help offer food security to the 8.0 billion inhabitants projected for 2025, the world needed another Green Revolution. The Green Revolution that began in the 1960s has helped maintain the food supply ahead of the demand in the last 30 years. Duplicating and triplicating production granted more time for developing nations to start addressing the population's rapid growth. The first revolution represented only a "temporary success", as observed by Norman Borlaug[2], who was one of its main promoters. Borlaug indicated that it is not enough to increase production of existing agricultural lands, but that it was also crucial to contain population growth.

The term transgenic "appeared" for the first time in scientific literature toward 1983. The first among these (soy, corn, cotton, canola, and vegetables, especially tomato) were authorized for consumption since 1993, maximizing seeds and race through horizontal transgenesis is what has come to be known as the second Green Revolution.

The "second Green Revolution" seeks to create and cultivate "new plants". Obtaining these clones is not based on crossing, hybridization, and cross-pollination techniques. In effect, the new methodologies are aimed

[1] The review on the topic has been constructed by students from the Masters in Environmental Science at Universidad Jorge Tadeo Lozano and it is frameworked within the post-doctoral research on Geosciences and Landscape Ecology led by Agrologist Grace Andrea Montoya Rojas, PhD in the biodiversity and abiotic medium line of research of the GADES research group at ECCI. The project containing this research refers to *Edaphology as Bioindicator of Climate Change* directed by Professor Montoya, since 2006.

[2] Norman Ernest Borlaug (Cresco, Iowa, USA, 25 March 1914 - 12 September 20091) was an agronomy engineer, geneticist, phytopathologist, humanist, and is considered by many the father of modern agriculture and of the Green Revolution. His efforts during the 1960s to introduce hybrid seeds onto agricultural production in Pakistan and India provoked a notable increase of agricultural productivity, and some consider him responsible for having saved over 100-million human lives. «Norman Borlaug—Over 245 Million Lives Saved», Scientists Greater than Einstein: The Biggest Lifesavers of the Twentieth Century, Quill Driver Books, 2009, ISBN 1-884956-87-4.

at cell culture, protoplasts, and tissues, besides techniques of genetic recombination to achieve great biological diversity from molecular and cellular mechanisms [2]. Currently, development of *in vitro* cell and tissue culture techniques, as resource to improve varieties with desired characteristics, has permitted significant progress in solving different problems in crops of economic importance, having achieved a novel development.

Cell culture and plant tissue constituted the big biological diversity, which projected in the field of biotechnology, open quite interesting perspectives in the search for new and useful solutions [3]. The concept of second Green Revolution is being expressed in agriculture in two main directions: creation of insecticidal plants, particularly by introducing toxic genes into the seed, especially *Bacilus thuringiensis*, which are transgenic Bt in cotton and corn, and the creation of seeds resistant to herbicides, led by the "Round-up Ready", with relation to glyphosate, which is the case of transgenic soy.

Discussions on the benefit of these new technologies versus the damage and impact on diverse factors like genetic diversity, the social effect, decreased possibilities for small farmers, alteration of ecological relationships, decreased biomass for the production of organic soil, economic expansion of companies that control these techniques, effects on hydric sources and other organisms, climate change, among others is quite broad and each branch has convincing arguments for its defense.

This work carries out a review of the process as such, without airing opinions to that regard, but simply showing the results generated, the applications, and the development worldwide and in Colombia. The purpose of this review was to understand the causes and consequences leading to the second Green Revolution, as a movement to raise awareness on the modification of nature at the service of our species and recognize the importance of sustainable agricultural production as a mechanism of human survival, in a growing population competing for natural resources.

2. Green revolution

When we speak of the Green Revolution, we refer to the need for food security [1], this refers to a state's capacity to preserve, protect, and use genetic resources of animal, plant, and microbial origin to guarantee food production for the human population of its community. The growth of human population has been explosive; in 1994 it was 5.6 billion, by 2000 it was 6.2 billion. According to data from the United Nations Organization Population division, 10540 children are born every hour in the five continents, this means 252,960 people are born in the world every day. This is how in total, according to figures obtained from the U.S. Census Bureau, the world already has over 7.0 billion inhabitants. However, the population increase does not remain there. Projection on what will happen over the next years increasingly alert specialists in charge of studying this phenomenon. In general terms, institutions like the UN predict that by 2045 or 2050, the world will be inhabited by two-billion more people than what are now registered [4].

This panorama permitted different international organizations to discuss a strategy with which to guarantee food security to developing nations, herein, emerged the idea of GREEN REVOLUTION and currently – with uncontrolled population growth – TRANSGENIC CROPS. The Green Revolution is generally known as the period during the second half of the 20th century (approximately between 1960 and 1990), when the greatest technology transfer occurred in the agricultural sector by developed nations to prevent food shortages in developing nations. Basically, from the positivist paradigm, what was sought was to increase crop yield through technological packages designed for the contexts of developing nations, mainly based on the use of agrochemicals, genetic improvement of seeds, irrigation, drainage, and agricultural machinery. [3]

From the prior definition, we can highlight two important moments: the first Green Revolution, which generated the total application to vegetable improvement from knowledge of classical genetics developed from the discoveries by Mendel[3]. Increased yields obtained in

[3] Gregor Johann Mendel (20 July 1821 – 06 January 1884) was a catholic Augustinian monk and naturalist born in Heinzendorf, Austria (currently Hynčice, Nový Jičín district, Czech Republic) who described, through works he conducted with different varieties of peas (Pisum sativum), the Mendel laws the rule genetic heredity. The first works in genetics were conducted by Mendel. Initially, he conducted seed crossings, which were characterized were bred in different styles and some in the same form. In his results he found dominant characters, characterized for determining the effect of a gene and recessive characters that did not have genetic effect (expression) on a heterozygous phenotype. (Bowler, Peter J. (2003). Evolution: the history of an idea. Berkeley: University of California Press. ISBN 0-520-23693-9).

cereals assumed a profound alteration of the agricultural systems of tens of developing nations. [4] Historically, its beginning could be considered after the end of the First World War; however, its global expansion occurred much later, during the Second World War, when big industry, above all in the United States, developed a huge accumulation of military technological innovation.

The birth of la second Green Revolution, based on the application of genetic engineering to improving cultivated plants took place in the United States during the 1940s, developing in Mexico during the 1950s (the Rockefeller Foundation began its Mexican Program of Agriculture, concentrated mainly on improving corn and wheat) and from there it spread throughout the world with the firm idea of modernizing agriculture and ending hunger in developing nations. Its scientific basis is molecular genetics, which developed from the discovery of the DNA structure by Watson and Crick in 1952. This Green Revolution sought mainly to create genetically modified organisms (GMO), better known as transgenics. These are organisms created in the laboratory with certain techniques that consist in the transference, from one organism to another, of a gene responsible for a given characteristic, manipulating its natural structure and, thus, modifying its genome.

According to some authors, green revolutions are divided into three, counting the first that took place during the Neolithic era (8500 BC), which consisted in the initial domestication of the main vegetable species we now cultivate; [5] the second Green Revolution developed as of the 1990s with progress in genetic engineering of agricultural products and xenotransplantation, among others; and the third Green Revolution or bio-revolution, which is under way with eco-sustainable agricultural and livestock production and completely organic free of transgenics.

The Green Revolution based on food security, requires a series of alternatives to respond to population growth, some of these are: broaden the base of crops used in human nutrition because we only consume 20 species of the 250,000 described; increase the yield of current crops, making it necessary to manipulate the genetic and environmental component; increase the agricultural frontier, which is complex given that European and Asian countries are densely populated and the South American and African countries should not be intervened by using new technologies like genetic engineering of plants. Stemming from the previously mentioned elements, it is necessary to understand some related terms, as shown ahead.

2.1. Biotechnology

The European Federation on Biotechnology (EFB) considers biotechnology as the integration of natural sciences and organisms, cells, parts of them, and molecular analogues for goods and services. It is divided in two: traditional and new; traditional biotechnology refers to conventional techniques that have been used for many centuries to produce beer, wine, cheese, and many other foods, while the new biotechnology includes all the methods of genetic modification through Recombinant DNA and cell fusion techniques, along with modern developments of traditional biotechnological processes [6]. Hence, the integration of diverse disciplines, as illustrated in Figure 1[4].

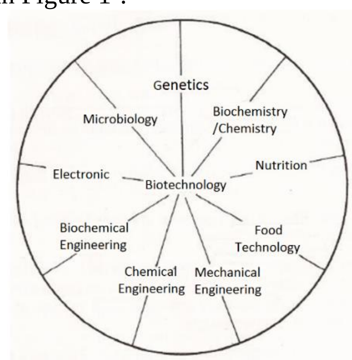


Figure 1. Disciplines integrated in biotechnology

One of the differences between Green Revolution (GR) and Agricultural Biotechnology has to do with the impulse given to both technological processes, given that the first was promoted by government with support from international organisms like FAO, the International Monetary Fund, the Bank of Mexico, and the World Bank (Buttel, *et al*, 1990 in Cota, H *et al.*, [7]); that is, the GR developed within a context of intervention by government, and biotechnology has not had the same government support, *i.e.*, it is within the private-entrepreneur sphere. Besides, it is considered that biotechnology has greater impact upon more social settings, unlike the GR that is aimed only at the agricultural sector, especially to productive increase.

An element that is one of the big similarities that exists between the GR and biotechnology, is that both were conceived as exclusionary technologies, given that the GR, although distributed massively, only commercial producers could apply the complete technological

[4] http://www.amc.edu.mx/biotecnologia/biotecnologia.htm. Consulted November 2013

package because they had the necessary capital to acquire all the inputs and equipment needed to use it. With biotechnology, history is repeated, given that – likewise – it is the commercial producers who have access to technology and markets to sell their products. Which is why, again the small producers and/or farmers are excluded from this "modernization" of agriculture. [7]

2.2. Genetic engineering

Genetic engineering has been defined as the formation of new combinations of inheritable material through the insertion of molecules of nucleic acids, produced by any medium external to the cell, in virus, bacterial plasmids, or other vector systems, which permit its incorporation into host organism in which said process does not occur naturally and which is capable of continuous propagation. In essence, genetic technology is the modification of an organism's genetic properties through the use of technology of recombinant DNA. [5]

2.3. Transgenic crops

Transgenic, biotechnological, or genetically modified (GM) crops are the result of the application of the technology of recombinant DNA in agriculture. These types of organisms are constituted with the transference of foreign genes (transgenes) of any biological origin (animal, plant, microbial, viral) to the genome of plant species cultivated. The GM crops are used in the world since 1996 and in December 2010 there were 1-billion ha cultivated. [8]

The GM crops used in global agriculture are primarily soy, cotton, corn, and colza, which express transgenes derived from bacteria and confer resistance to lepidopteran insects (RLI) or tolerance to some herbicides like glyphosate and gluphosinate ammonium. An important contribution of transgenic technology is the production of drinkable vaccines against deadly disease. The two main features that have been introduced to GM crops available commercially are resistance to insects and tolerance to herbicides. A few crops have been liberated with the characteristic of resistance to virus (papaya, potato, and pumpkin), using genes derived from the very virus. The source of insecticide toxins produced by commercial transgenic plants is the soil bacteria *Bacillus thuringiensis* (Bt).

2.4. Third Green Revolution

Some authors state that now we are living a third Green Revolution based on ecological, organic, or biological agriculture. This manages to framework all the agricultural systems that promote healthy and safe production of fibers and foods, sustainable from the environmental, social, and economic points of view. These systems stem from the soil's natural fertility as the base for good production without modifying the demands and natural capacities of plants, animals, and the landscape, seeking to optimize the quality of agriculture and the environment in all its aspects. All the processes applied to obtain an organic product must be guaranteed to consumers through a certification system.

[9] conducted research called transgenesis and culture: sustainable debate, which shows the current panorama of transgenic foods and concludes that the planet does not need these to address the inequality in relation to access to foods; the article summarizes the following points: our transgenic crops necessary? Since long ago it has been known that hunger in the world is not due to problems of food production but to distribution. Never before had humanity produced so many tons of food (enough for a daily supply of 4.3 pounds per capita/day), but never before had so many people been registered to go hungry. Hunger has political and economic roots.

Speaking specifically of Colombia, we see that our country has enough arable land in inter-Andean valleys, the Caribbean plains, in the plateaus, and even on the hillsides to supply its current and future population. The main limitations refer to land ownership. Our country is one of the countries with the biggest arable land large estates. The mere purchase of lands by drug traffickers, perhaps the biggest process of contemporary agrarian reform in the world, has put almost 4-million ha of land during the last decade in the hands of a few individuals who use it for extensive cattle ranching. Does Colombia need to import seeds of transgenic crops to improve agrarian production? The answer is no.

The diversified fields are by themselves strategies of pest and disease control because within an environment of abundance food offer there is also a large amount of organisms related amongst themselves and to the cultivated and emerging plants, facilitating the agrosystem's self-control. Modified plants are not required within a context of such high adversity in the country with so many climates, land characteristics, and soils[5].

3. State-of-the-art of the green revolution

The state-of-the-art of the Green Revolution centers on the analysis of the pros and cons this practice can bring to the community, the environment, and science. Thus, Figure 2 shows some research conducted in this setting within the three spaces: Green Revolution, transgenics, and biotechnology in general.

To start, regarding the conceptions around the first and second Green Revolutions, [5] makes a historical account of the first and second Green Revolutions by emphasizing on the consequences and accomplishments of the first along with the impacts the second could have in our society and in our environment in the near future. The author discusses the theory of “primitive accumulation” described by economists during the mid 19th, and described as the modern social inequality, where there is asymmetrical accumulation of those who own the means of production against those who are part of the work force. After 500 years of starting the primitive accumulation and after nearly 60 years of the Green Revolution, some social movements hold that, currently, an analogous process is in full development throughout the world because the ten biggest biotechnology companies in the world (dedicated to subproducts for the pharmaceutical industry and agriculture) are only 3% of the totality of these types of companies; controlling 73% of the sales. The main ones are Amgen, Monsanto, and Genentech.

Cano, C. [10] reflects upon increased international prices of foods, particularly grains and vegetable oils. Additionally, the author shows how in order to satisfy demand; the agricultural offer should increase by 40% by 2030 and 70% by 2050. Planting new areas, mostly in Latin America and Africa, will be conditioned by availability of water; adoption of appropriate biotechnologies; and use of lands that, although suitable, are idle or underused in inefficient cattle ranching systems. Cano concludes that only technical change can moderate the occurrence and adverse impact of exogenous conflict from the high cost of foods upon inflation. Hence, it is of high priority and pressing to adopt mass solutions through innovation in biotechnology.

Ruíz, C [11] published the main conclusions of a debate conducted during the bioethics masters program where the central theme was: “let the harvest grow”, a package with pros and cons. With biotechnology, a whole package of solutions is available for farmers, consumers, environment, research, and society; said solutions are especially attractive due to their ethical-political stance: confronting the challenge of population increase and the blemish of world hunger, but in the counterbalance arguments emerge on biosecurity, demanding the interruption of research on these techniques and the la commercialization or deliverance of products because these would be potentially dangerous and susceptible to perverse applications.

Besides, an important element of debate is that do not have enough information on the behavior of artificially inserted genes; we do not know if these can mutate, how and when; how do they interact with other genes; what effect can promoter genes have, etc. The concern is that allergenic genes or resistance to antibiotics could possibly be transferred to other organisms in the same species or to different species. The modified species could compete with wild and local populations and end up substituting them. Thus, the author closes the debate with the following phrase: “*bioethics calls on us to delve into our idea of autonomy and on the whole of freedom*” Upon presenting the discussion held by several authors regarding the Green Revolution, we note that some consider that it is not a thing of the past, but that it is in vogue in the world of agriculture and call it the third Green Revolution. Other authors state that the third Green Revolution is a current fact; the first was during the Neolithic era with the start of agriculture, and the second during the 1960s.

Throughout the article, the author points to the history of transgenesis in Colombia and includes the following: scientific research is amended to elements rarely considered by scientists. The first element is that scientific research permits the penetration of capital in sectors of society that would seem inaccessible to the business world; the second is that the socioeconomic profit from products resulting from scientific research guide the perception of what society (including the scientific community) considers true of nature.

Likewise, García, F [12] mentions three green revolutions and emphasizes on the article on the history of scientist Barbara McClintock,[5]an important researcher in the field of genetics, which mentions the objectives of

[5] Barbara McClintock1 (Hartford, the United States, 16 June 1902 – Huntington, the United States, 3 September 1992) American scientist specialized in cytogenetics and obtained the Nobel prize in Medicine or Physiology in 1983. McClintock received her PhD in Botany in Botany in 1927 from Cornell University, where she then led the group on corn cytogenetics, her field of interest throughout her career. By the end of the 1920s, she studied the changes that occur in chromosomes during corn reproduction, evidencing through microscopy methods developed in her laboratory processes as fundamental as genetic recombination, which is produced during meiosis. Indicative of the genetic map in corn, she described the first map of this genome’s binding and highlighted the role of telomeres and centromeres. Due to the high level of her scientific work, she was awarded on several occasions, becoming part of the National Academy of Sciences of the United States in 1944. Creighton, Harriet B., and McClintock, Barbara (1931) «*A Correlation of Cytological and Genetical Crossing-Over in*

modern improvement with some examples of adhesion of genes on some organisms. The article closes with the reflection on the social consequences of scientific progress.

Lastly, with the arrival in Colombia of the Green Revolution, Quintero, M [2] researches on the effects of the Green Revolution on the *chontaduro* (*Bactris gasipaes*) crop. This research shows all the negative effects of transgenesis on the *chontaduro* crop and proposes the application of agro-ecology for which sustainability lies on the capacity to perpetually harvest certain biomass of the system with the capacity to renovate itself or whose renovation is not at risk. Table 1 briefly describes some reflections on the topic.

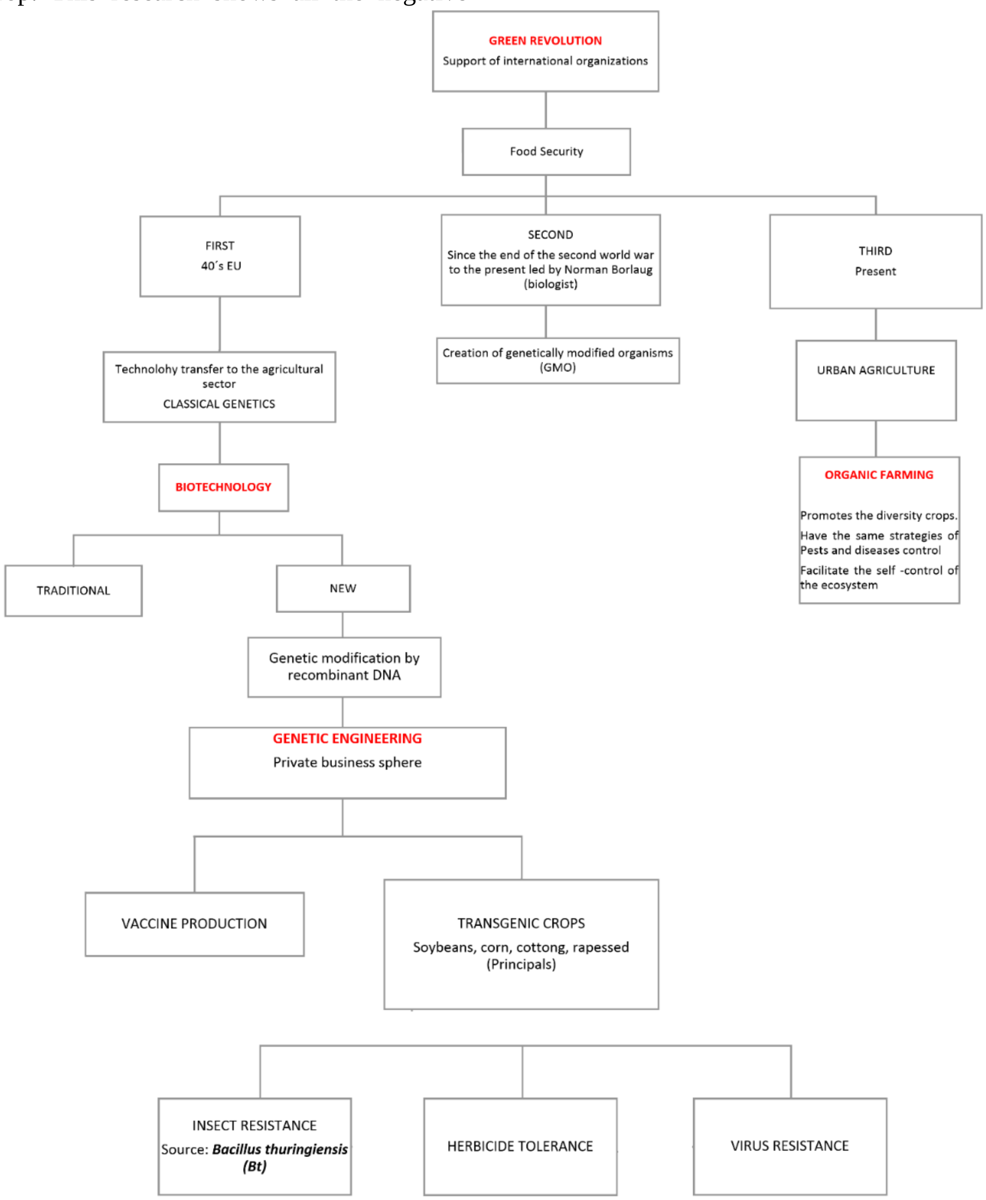


Figure. 2. Conceptual map of the Green Revolution

Zea mays». Proceedings of the National Academy of Sciences 17:492–497

Table 1. Reflection articles on the Green Revolution

García, F [12]	Also mentions three green revolutions since the Neolithic era and their discussion revolves around the social implications of scientific research
Ruíz, C [11]	GMO debate from bioethics within a context of scientific ignorance toward the response of organisms within environments in relationship to other living beings
Ceccon, E [5]	Historical account of a first and second Green Revolution, discussion of the theory of primitive accumulation
Cano, C. [10]	Analyzes food prices and requirements with relation to the agricultural demand, emphasizing on the need to implement biotechnology at greater scale.
Quintero, M [2]]	Analyzes the negative effects of transgenesis in the *chontaduro* (*Bactris gasipaes*) crop and proposes the practice of agro-ecology

3.1. Research on Transgenesis and Biotechnology

After the previous context, when speaking of Green Revolution most investigations point to transgenesis (Table 2), some investigations in this area are:

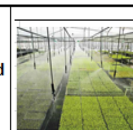
Chaparro [8] conducted a study on the application of genetically modified crops throughout the world, explaining which are the ones most used – along with their advantages. Additionally, the author reflects on the biological risks, concluding that some of these are the following: negative effects of transgenic proteins on non-target species and humans; flow of genes from GM varieties to conventional varieties; generation of biotopes in landscapes resistant to transgenic proteins; impact on biodiversity. Some advantages are: decreased environmental impact when no longer adding active ingredients; economic profit when diminishing production costs and increasing production. Table 2 illustrates some research on transgenesis; here, we can see how current research in this field is guided to benefit humans with the creation of vaccines or to obtain other chemical compounds that can improve health.
Lastly, regarding biotechnology, it currently has the following lines of research: development of new therapies and treatments for numerous human and animal diseases; design of diagnostic tests to increase disease prevention and pollution control; improvement of many aspects of plant and animal agriculture, cleaning and improvement of the environment; and the design of process of cleaner industrial manufacture.

Additionally, in the field of biotechnology there is important research by Bellver Capela, V (2012) [13], which offers a panorama of the biotechnologies applied to human life, emphasizing on its profound evolution since the late 1990s and on its extraordinary impact on society. In light of some especially significant biotechnological accomplishments between 2010 and 2011, the author holds that the relationship between biotechnology and society endured radical change in early 21st century, leading to a second stage in the development of biotechnology, which the author proposes to denominate as “biotechnology 2.0”.

Table 2. Studies on transgenics and its purposes

Jiménez *et al.*, [13]	Had broccoli hairy root crops to produce protein L1, which is highly antigenic. It is an important research for the production of vaccines against HPV.
García *et al.*, [12]	The research shows the results of using transformed roots of *Brassica oleracea* var *italica* (Broccoli) to produce human insulin. It concludes that the presence of cDNA corresponding to preproinsulin and proinsulin was ß-glucuronidase positive for several lines. Although the yield was variable, five lines showed appropriate values with potential use as production study model in bioreactors.
González et al., [14]	Its objective was to express a recombinant fragment of the CagA protein with a tail of histidine (rCagA) that can be used in a rapid serological test to detect *H. pylori* infection and classify it in positive or negative CagA-.
García *et al.*, [15]	Presents results of the study of crops of transformed roots of *Brassica oleracea* var. *italica* (Broccoli) to produce the human growth hormone (hGH1). Due to the high demand for this hormone, an alternative is the use of plant biotechnology to produce heterologous proteins.
Greger [16]	Analyzes the regulation of transgenesis in livestock, showing how productivity limits have been reached possible through selective reproduction. Thus, animal agriculture should respond to society needs.
Tyrda *et al.*, [17]	The aim was to compare the thyroid tissue structures of transgenic rabbits that express human coagulation factor VIII and compare it to non-transgenic rabbits. The analysis did not reveal significant differences (P> 0,05) related to the volume of the basic thyroid structures and in the measurement of the height of the epithelium and nuclear diameter of the follicular cells. In total, this study does not show negative effects of WAPr-hFVIII transgenesis in the rabbit’s thyroid gland structure.
Bae *et al.*, [18]	The research question is if the BAC technique is obsolete, the study concludes that this technique has disadvantages like the complicated construction of vectors. This is how new techniques have been developed that do not have these problems like effector nuclease (Talens) and zinc finger nuclease (ZFNs).
Meredith *et al.*, [19]	Genetically modified mosquitoes refractory to disease transmission are seen with great potential in the delivery of new control strategies. The *Streptomyces phage* phiC31 system has been successfully adapted to be directed to the site of integration of the transgene in a range of insects. In the struggle against malaria, it is imperative to establish a broad repertoire of both effector genes against malaria and specific tissue promoters to regulate its expression.

1941	1942	1944	1946	1947	1951	1953	1963	1968	1974
Foundations First Green Revolution		wheat disappears by diseases		Colection of germplasm			International center for the improvement of corn and wheat		27 millions hectares sown with new varieties
USA	Sonora Mexico	bengala india	brasil	Argentina	USA	India	Mexico	India	Latin america Asia Africa
	Drivers of the green revolution		Corn monocultures	Hybrid		Rice and wheat monocultures		Rice miracle	

1990	1992	1993	1994	1996	1997	1998	1999	2000
Second Green Revolution	Germplasm banks transformation		Agroecological systems in third world countries		Sustainable production of wood and fruits		Sustainable management of natural integrated resources	
	FAO	Asia	Organic Farming	Nicaragua India Filipines	Peru	Ecuador	Mexico	Biorevolution Hannover
Environmental alert: transgenic security		Experimental Mechaning territorial		Sustainable agriculture pest integrated management		Organic Farming		Brasil : green fertilizer cover crops

2004	2005	2006	2007	2008	2010	2011	2012
	Bt 10 Transgenic corn (No tested for consumption)		Agroecological systems in third world countries	Corea	Sustainable production of wood and fruits Nanotechnology		Sustainable management of natural integrated resources Argentina
Areas of genetically modified crops grow	Syngenta	Agrobiote	Bayer CropScience	New Green pacte	G.M. Technology	Farm- Laboratory	Sustainable underdevelopment
USA (59%) Argentina (20%) Canada, Brasil, South Africa, China		Monsanto Syngenta Bayer CropScie Pionner Dow AgroScien		United Nations program for environmental		Xenotransplants (Organs and tissues, agricultural and livestock)	

Figure 3. Time line, International context

The article is based on human reproduction through biotechnology; seeking to develop predictive medicine based on the knowledge of our genes. This will defeat the growing problem of infertility in the world; human embryo stem cells will be an endless source of repair materials to regenerate our organism and cure serious disease that are now incurable; cloning of embryos will allow the stem cells obtained to have the same genetic characteristics as its receptors and will, thus, avoid rejection problems. Upon these horizons of hope it is difficult to resist. With which Biotechnology 2.0 stops being a tool to improve human life and becomes the means to obtain something better than human life, that is, post-human life.

1.1. National and Internacional Context of the Green Revolution

Within the state-of-the-art of the Green Revolution conducted for this document, the authors, herein, constructed two time lines: one for the international context and another for Colombia, as illustrated in Figures 3 and 4.

After the first Green Revolution during the 1960s, when cultivation of plants and use of fertilizers helped to increase yields, came the need for a "second Green Revolution", which included biotechnology permitting better yields and availing of crops. In Colombia, the practices of this second revolution are almost new and has had boom during the last decade; the most important facts are:

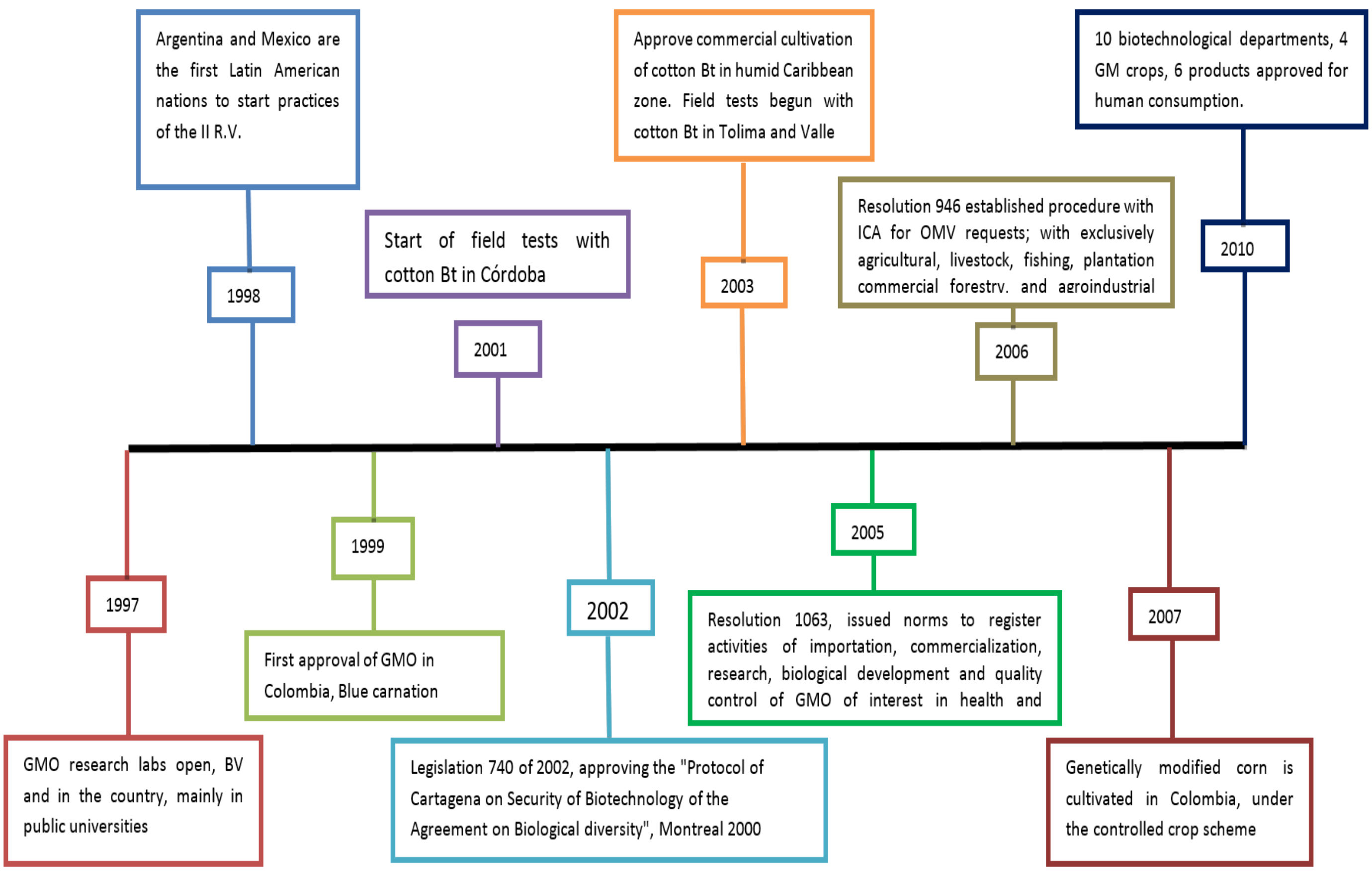


Figure 4. Time line, national context

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- Colombia cultivated 18.874-thousand ha of biotechnological cotton in 2009, against 28-thousand ha in 2008; the genetically modified cotton planted is simultaneously tolerant to herbicides and resistant to insects. It continues being the crop of highest adoption in Colombia

- Since 2002, Colombia began cultivating cotton Bt with approximately 2-thousand ha. Since that year and until 2009, adoption of this GM crop has grown significantly until reaching a peak in 2008, with 28-thousand ha cultivated in the national territory.

- The GM corn has been cultivated in Colombia since 2007, under the "controlled crops" scheme and it is still not approved for commercialization. This GM crop reached 16.8-thousand ha in 2009, which meant an increase of 1.8-thousand ha with respect to 2008, when 15-thousand ha were cultivated. The biggest adoption in our fields is that presenting resistance to lepidopterist insects, with a cultivated area of 12,320 ha.

- In November 2009, the Ministry of Social Protection approved the importation for human consumption to two events of genetically modified cotton from Monsanto, one of corn from the same company, and two of corn from DuPont Colombia S.A.

2. Applications

It is worth mentioning the practical uses of the Green Revolution; through the joint use of Mendelian genetics and statistics during early 20th century, which was constructed as science and art of genetic improvement of crops. Through intensive exploitation of the so-called hybrid vigor, cereal yields were significantly increased, at the same time as inter-variety and inter-specific hybridizations, accompanied by cytogenetic manipulations, which were useful to move genes of resistance to disease and to insect plagues from foreign donors to cultivated varieties. Plant improvement was then accelerated, with the development of the Recombinant DNA technology, which permits transfer of foreign genes to the genome of cultivated species.

According to Chaparro [8], pest and disease control of important crops like rice (*Oryza sativa L.*), wheat *Triticum aestivum L.*), barley (*Hordeum vulgare L.*), corn (*Zea mays L.*), and cotton (*Gossypiuhirsutum L.*) were notable accomplishments; also, biofortification of crops is another important development in the struggle against hunger and malnutrition. Golden rice, genetically enriched with vitamin A and iron, for example, has the real potential of saving millions of lives. Another interesting application of transgenic technology is the production of drinkable vaccines against deadly disease.

Currently, efficient and reliable protocols are available for a variety of plants: cereals, leguminous plants, fodder, oleaginous crops, crops for fibers, ornamental plants, and forest species. Genetic transformation offers direct access to an unlimited gene bank, previously unavailable to genetic improvers.

Also, the second Green Revolution contributes in adaptation to extreme environmental conditions, as well as to the possibility of regenerating and recovering soils, permitting the prolongation of the commercial life of products; besides, improving nutritional value and edaphic aspect. Another of the applications is the production of plants with highly specialized purposes (precursors of vitamins, biofuels, medications...); reduction of herbicide and pesticide use, with obvious economic advantages on the environment and health of farmers.

In all, a package of solutions for farmers, consumers, environment, research, and society, but above all especially attractive due to its ethical-political stance: face the challenge of population increase and hunger in the world. In practice, important promises; the second Green Revolution – according to its promoters increased the production of genetically modified species; permits including zones with almost unproductive soils because of their salinity; promotes a more rational use of water; promotes decreased use of insecticides, generating huge environmental benefits.

The context of the "Second Green Revolution" is not complete without considering the concept of comprehensive exploitation, that is, without adding at least one link, that formed by animals. On one side, over one third of the global production of transgenic cereals is destined for animal nutrition, which means an important competitor in the debate on hunger in the world, a high consumption of resources, a strong impact on these types of exploitations on the environment, and a new focus of liberation of transgenics that is not controlled. On the other hand, genetically modified animals destined for scientific research are a reality. The distribution problem could be even more complicated than currently. We would have to add increased sanitation costs, treatment in patients from other cultures, problems of identity, or the regulation of possible new species more or less human.

One of the most important purposes of these new avant-garde tendencies is that of becoming tissue and organ banks for xenotransplants. The new generations of transgenic animals could make differences among species obsolete. Organ scarcity would be a thing of the past; mistrust would be avoided upon the notion of death stipulated by science; organ trafficking would disappear; interventions could be planned ahead of time, no problem would exist between the time the organ is extracted and transplanted, for example.

With respect to animals, it does not make sense to speak of donors, but of sources of organs. Besides selecting the adequate species (possibly hog) and solving pending technical problems, unlike genetic modification or molecular fabrication in plants or other organisms, genetically modified animals used in xenotransplants, and in research in general, confront us with a problem that has not been debated much in bioethics. These are beings with capacity to suffer and with a rich emotional and social life. It must not be forgotten that the production of transgenic animals supposes a large series of experiments, and that specialists estimate the need for 10 to 20 years of research for these types of interventions to become routine practice. Throughout all these years – evidently – animals will be needed for research.

3. Discussion

The discussion is synthesized on the a SWOT matrix of the Green Revolution in each of the environmental components, fruit of interdisciplinary analysis and focused on research of the transformations of the human landscape and environment, an aspect that motivated writing this document

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	WEAKNESSES	OPPORTUNITIES	STRENGTHS	THREATS
Atmospheric component	Variation in the proportion of its compounds like water vapor, carbon dioxide, and suspended particulate material Contamination of different origin, generating acid rain, increased greenhouse effect, acidifying lakes and swamps, decay of physical infrastructure.	Effects of its alteration are not produced only in the area of influence of the source; they are of global scale because they exceed the emission area.	Follow up its dynamics, variations in its composition, and phenomena occurring in it. Joint and agreed-upon control and mitigation measures Monitoring and follow up of air quality.	Receptor of physical, chemical, and microbiological substances. Incidence on human activity, infrastructure, wellbeing of ecosystems and climatic behavior Cross-border mobility of contaminants. Chemical transformations of most primary contaminants.
Component hidrosférico	Scarcity. Alteration of quality. High vulnerability. Quality in function of use. Receptor of liquid and solid contaminants.	Hydric offer. Recyclable in natural and artificial manner.	Diverse uses (human, domestic, industrial, and agricultural). Varied supply forms (reservoirs and dams, deviations of currents, wells, desalinization, rain water)	Poor availability of large amounts of fresh water. Non-homogenous distribution of water. Physical, chemical, and organoleptic properties. Facilitates mobility of contaminants among flora, fauna, atmosphere, and soil.
Geospheric component	Consider it as support of plants and storage deposit for materials and diverse wastes. Loss of its physical properties (color, texture, structure, density, porosity, and water retention). Alteration of its chemical properties (pH, CIC and CIA) and biological diversity. Exceed its load capacity and decrease of its self-purification capacity. Few efforts to control its contamination. Conflict between uses of diminishing soil to agricultural productivity.	Natural support for activities conducted by dynamic and constantly evolving humans. Great capacity for self-purification. Potential use defined by its physical, chemical, and microbiological properties. Hosts large diversity of microorganisms.	Recognition of the importance of protecting it and its adequate management. Development of technologies like SIG that facilitate their study and understanding. Variety in treatment systems and control measures for its contamination.	Mobility of contaminants defined by physical, chemical, and biological characteristics. Its physical properties cannot be recovered. Displacement of contaminants to other receptive mediums like water and air. Its composition can generate endogenous contamination. High susceptibility to alterations. Adaptation tests are not conducted to know the responses of the GMOs. Contamination of surface and underground water.
Biospheric component	Transformation of fragile conservation lands to crop lands. Vast extensions of monocrops and intensive cattle ranching. Genetically modified organisms (GMO) liberated onto the environment. Replacement of autochthonous species by species genetically modified or not. The importance of plants and animals is in function of benefiting humans. Use of broad spectrum herbicides and insecticides. Each organism and each part of its genome is seen as a potential patent. Suppose that climatic and edaphic conditions are uniform.	Characteristics like nitrogen fixation and photosynthesis are specific for each plant species. Indispensable for ecologic equilibrium of ecosystems. DNA is the fingerprint for each species. Genetic expression of cells regulated by a complex network of processes. Great possibility of creating resistance to herbicides and insecticides used intensively. Phenotype characteristics offer them possibilities of interacting for biocontrol	Development of bioethical aspects. Great variety of plants and animals. Biological control strategies can be developed against insects and pests. Selection of seeds y animals for reproduction.	Decreased biodiversity. Development of new weeds. Alteration of natural control and equilibrium processes of ecosystems. Plagues can create resistance to the insecticide, hindering their control. Death of beneficial insects that pollinate other plant species. Impact on established populations because interactions are unknown between local species and genetically modified species. Susceptibility to adverse factors from the environment because it does not have the multitude of life expressions to control it.

	WEAKNESSES	OPPORTUNITIES	STRENGTHS	THREATS
Anthropospheric component	Non-sustainable production and consumption forms. Conflict of use on soil resource. Transformation of fragile and conservation lands to crop lands. Demographic growth. Lack of guarantees for small farmers from developing nations to access technological innovations. Monopoly of commercial sectors that provide agricultural inputs. Capacity of transformation of agricultural and food production. Production of transgenic crops (corn, soy, canola, and cotton) is not as expected. Too much research time and economic investment for such few crops and characters. Change from scientific revolution to technological revolution and determine the way to produce. Technical-economic paradigm and not of agricultural production. Subordination of social, economic, and cultural relations. Private entrepreneurial context with little or no government intervention.	Improves nutritional quality of foods. Requirements for less machinery to eradicate weeds. Herbicides and pesticides for transgenic crops are generic and, hence, biodegradable and less contaminating in soils and water. Decreases production costs. Reduction in losses due to pests or weeds.	New strategies to meet the global food demand. Technological progress to increase the yield of some crops. Adoption of strategies like the 21 Program and the Rio Declaration during the 1992 United Nations Conference on the Environment and Development (CNUMAD) reveal a global concern for the environment and sustainable development. New technologies transform the economy and society. Solve problems caused by technologies previously developed. Scientific revolution. Technology as dynamic element of the economy Patents on organisms, products, and processes derived from biotechnological research. Capacity to modify products, improve plants or animals and develop organisms for specific use. Duty of biotechnology defined by bioethics	Decrease of lands with agricultural potential. DNA as raw matter for biotechnology. Manipulation of genes responding to economic interests. Genetic resources seen as commercial goods and not as patrimony of humanity. Genetic engineering comprises techniques that permit modifying inherited characters. Anthropocentric position. Eliminate characteristics or modify them and not solve in-depth economic and social problems. Impacto n salud. Commercially, no identification is available on the products originated from transgenic plants or animals. Weakening of a characteristic to maximize a more “useful” one. Ignores ancestral knowledge of farmers and native Indians. Contamination of soils and surface and underground water.

4. Conclusions

The Green Revolution is known as a means of agricultural production created in industrialized societies, consisting of maximizing races and seeds through technological packages.

Most genetic improvement of crops and the consequent increase of yields was the result of conventional improvement. Those tools, although slow and sometimes tedious, will continue playing a very important role in photo-improvement programs. Also, GM technology has the ability to change a plant's genotype in a relatively short period of time, and can help to design more nutritional plants, among other traits of interest. However, this new technology only complements, does not replace, the conventional improvement of plants. Conventional and modern technologies should go hand-in-hand to accelerate plant improvement and contribute to guarantee global food security.

In Colombia, currently OMG crops are implemented in 10 departments; some of the crops are: cotton, corn, rice, flowers like carnations and roses. Additionally, corn is cultivated under the system of controlled crop. Importation, commercialization, research, biological development, and quality control are controlled by Resolution 1063.

Applications of the Green Revolution include pest and disease control, resistance to herbicides, adaptation to extreme conditions in crops, increased duration of post-harvest time of agricultural products, and their biofortification.

Man introduces a conflict of use on the soil resource because of the transformation of fragile and conservation lands to crop lands in which transgenic crops are being implemented in higher percentage; these can be detrimental for the soil due to loss of the physical, chemical, and biological properties, exceeding the load capacity and diminishing self-purification.

The ecological equilibrium of systems supported by the soil is naturally transformed, bearing in mind the different natural phenomena being generated by the climate changes of the Quaternary; however, certain activities by mankind, like overexploitation of the soil, can infringe the ecological equilibrium, causing natural phenomena to move in the human rather than ecological scale, placing biodiversity at risk. Transgenesis could be an apparent solution to diminish pressure upon the soil, but it can lead to a huge sacrifice on genetic richness and the human genome.

Discussion on using transgenics and biotechnology remains open; research is increasingly discouraging on the consequences on human health and its environmental setting, but it should also not be ignored that genetics has saved lives and improved the quality of life in certain sectors of society.

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