PRIZE

“House of Representatives of the Principality of Asturias-International Society of Bioethics (SIBI)” 2009

Mertxe de Renobales Scheifler

University of the Basque Country

(Spain)

“*More* sustainable food: Genetically modified seeds in organic farming”

Biography

Mertxe de Renobales Scheifler (Bilbao, 1948), Bachelor in Chemistry (University of Bilbao, 1975), and PhD in Biochemistry (University of Nevada, Reno, 1979). For 13 years she worked as investigator in several universities in the United States and as assistant professor in the University of Nevada Reno. Upon her return to the Basque Country (1988), after 2 brief years as head of the Biotechnology Section of Foundation Inasmet, she obtained a Professorship in Biochemistry of the University of the Basque Country/Euskal Herriko Unibertsitatea to work in the Faculty of Pharmacy. Among other teaching duties, she teaches two courses on transgenic foods in the Master Programs "Quality and Food Safety" and "Nutrition and Health", the origin of her interest in Bioethics. She has served as Dean and Associate Dean of the Faculty of Pharmacy and currently she is the Director of Quality of the Alava Campus. Her diverse research work on lipids is described in over 80 scientific publications. Since 1992 she is the principal investigator of a multidisciplinary research group focused on the biochemical, microbiological and technological aspects that influence the nutritional and sensory quality of sheep cheeses.

Edita: Junta General del Principado de Asturias
Sociedad Internacional de Bioética (SIBI)

Depósito Legal: AS.-110 - 2010

Impresión: Grafymak, S.L. - Gijón

Edición no venal

PRIZE
"House of Representatives of the Principality of Asturias - International Society of Bioethics (SIBI)" 2009

ISSUE

MORE SUSTAINABLE FOOD: GENETICALLY MODIFIED SEEDS IN ORGANIC FARMING

PRIZE 2009

“House of Representatives of the Principality of Asturias - International Society of Bioethics (SIBI)”

After thorough review of the papers received and accepted, and in accordance with the contens established in the basis for the summons, the Jury agrees that the Prize be bestowed to the paper with the highest grade, submitted unde the pseudonym:

TRANSGECOL

and the title: *“More sustainable food: genetically modified seeds in organic farming”*.

On opening the envelope exhibiting that pseudonym the author of the winning paper is disclosed to be:

Mertxe de Renobales Scheifler

Gijón (Spain), 18th December 2009

The Jury

President | *Members*

Marcelo Palacios (España)	Margarita Salas (España)	Erwin Deutsch (Alemania)	Santiago Dexeus (España)

MORE SUSTAINABLE FOOD: GENETICALLY MODIFIED SEEDS IN ORGANIC FARMING

Mertxe de Renobales Scheifler
Biochemistry and Molecular Biology Pharmacy Faculty
University of the Basque Country

Dedication

To Iker and Gorka, with my love and gratitude for your support and help.

Acknowledgements

I want to thank SIBI for the happiness and satisfaction that this prize has given me because it was totally unexpected and because it recognizes a work based primarily on my teaching experience, not on my research. Thanks are also due to my colleagues and friends, with whom I share the teaching of "transgenics" at the Faculty of Pharmacy, Drs. Marian Mz. de Pancorbo, Juan Carlos Ruiz de Gordoa and, particularly, Leire Escajedo. Dr. Escajedo was the motor behind the present work, pushing me to write it and improving it substantially after her critical reading of the draft. Likewise, I want to thank Dr. Jaime Costa for his generous and continuous help during the last several years answering my questions on agronomy and the intricacies of the European system for the authorisation of transgenic crops. Last, but certainly not least, my most sincere thanks go to our son Iker and to my husband Dr. Gorka Aulestia Txakartegi for their understanding, support and love during these months in which I spent nearly all my free time writing instead of doing other things of their preference. Eskerrik asko denori! Thank you all!

Table of contents

ABREVIATIONS

CIMMYT	International Center for the Improvement of Maize and Wheat (acronym in Spanish)
DNA	Deoxyribonucleic acid
DDT	dichlorodiphenyltrichloroethane
EFSA	European Food Safety Authority
EGE	European Group of Ethics
FAO	Food and Agriculture Organization
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development.
GMO	Genetically modified organism(s)
NGO	Non-governmental organisation(s)
UN	United Nations
USA	United States of America

CHAPTER I: FOOD PRODUCTION AND CARE FOR THE EARTH: KEYS TO THE CURRENT DEBATE

1.- Food production and care for the earth: keys to the current debate

Mainly in Europe, but also in the United States of America, intense debate is currently going on as regards the production of plant-origin food. In addition to other issues, the controversy centres around organic farming techniques as opposed to the use of genetically modified seeds in conventional farming. Organic food and genetically modified food tend to be presented before public opinion as two clearly separated blocks; two clearly differentiated methods that seem to be *inherently* linked to ethico-social and political options with respect to issues such as international trade, relations with developing countries, consumer defence and environmental protection. Defenders of both food production methods tend in this way to situate the crux of the matter in the ethical aspect of the method they are advocating, completely discrediting that of the other. We believe this to be a sterile controversy. It merely puts either party on the defensive, thus precluding the possibility of each one listening to the other's opinion. Clichés that are frequently resorted to in heated debates hinder understanding and reflection on the positive aspects the opposing alternative may offer.

Over the last ten years, such conduct has made it difficult to identify synergies, and those spaces in which it is possible to join forces. To a certain extent, perspective has been lost. Legislation, at least that enacted by the European Union, has not been of any great help because, perhaps due to the lack of co-ordination, rather than intentionally, it has been rejecting certain production methods while favouring others. This may explain why we feel that the time has come to study in depth exactly where these two points of view disagree and why, in order to afterwards embark on the search for those points on which there is agreement. We are encouraged in this endeavour by the conviction that sustainability and the guarantee of food security for all human beings are goals beyond compromise. In June 2009, the FAO announced for the first time in history that over one thousand million people in the world are suffering from hunger: that is to say, one in six[1].

The subject put forward by SIBI in this edition, namely, **"Transgenic and ecological food: bioethics aspects",** has served to inspire us to analyse, as objectively as possible, both food production methods within the framework of bioethics in its widest sense, while at the same time attempting to divest ourselves of any prejudices that we might have as regards the issue at hand. To this end we will use the definition of Global Bioethics proposed by Palacios as a guide:

"*the discipline concerned with the analysis of the advances and the use of science and technology in order to propose applicable ethical guidelines to reconcile these dis-*

ciplines with the due respect for human dignity and the protection and preservation of the environment, species and nature"[2].

We understand the word "preservation" in this context to refer to the care and respect, or simply to the protection, of the environment and biological diversity. The word "preservation", used as it frequently is in many different academic disciplines and in the mass media, may lead some people to think that it is possible to maintain the environment in a particular state which, obviously, cannot be defined. We see respect for nature as an approach to a reality subject to the laws of evolution, because nature is dynamic and changing, regardless of the existence of humans. All living beings have in some way left their mark, to a greater or lesser extent on the ecosystem[3] in which they have lived[4]. Being aware of the its grandeur and the impact that we are having on it, is the key to our commitment to refrain from pillaging it.

1.1.- Farming and food production

1.1.1.- Sowing to provide

Farming can basically be defined as a set of practices that we employ to grow a series of plants that serve as food, both for humans, as well as for domestic animals.

Nevertheless, as with the majority of human activity, it has several aspects. In addition to providing us with food for people and animals, farming also enables us to obtain textile fibres, fuel, medicinal products and decorative plants. Furthermore, it provides us with environmental and entertainment services, not to mention the part it plays in preserving many cultural traditions. Therefore, farming has three main facets: economic, social and environmental (Figure 1).

1.1.2.- Farming development: a historical overview

Humans, as do all living beings, interact with the ecosystems in which they live, altering them by their activities, such as the building of suburbs, of recreational areas and of industrial areas for all types of activity, as well as by farming, forestry, fishing and stock breeding activities. All such activities require the use of land that was previously covered by natural ecosystems, such as, for example, forests and meadows. Indeed, for some activities, increasing with the passing of each day, water media are likewise beginning to be used (rivers, lakes and oceans).

Animals, including the human race, cannot produce the compounds we need to survive without using other living beings, as, for example, plants can. Therefore, we have no alternative but to feed off them, or off other animals. Given the fact that we have to eat to survive, and that we are aware of the interrelation that exists between all living beings on earth, we have the moral duty to use the best that science and technology have to offer us at any given time in order to produce food, acknowledging that panaceas do not exist and that in all probability, it will be impossible to come up with a completely problem-free system, or systems.

Figure 1.- Main facets of farming

Taken from "Agriculture at a Crossroads – Synthesis report" (IAASTD, 2008; http://www.agassessment.org).

As far as we know, humans are the only living beings that are aware of their actions and thus can reflect on their relationship with the environment and the influence their actions have on the rest of the living beings in their surroundings. Furthermore, the impact of human beings on the environment depends very directly on the type of activity in question and the number of people pursuing certain activities. This also applies to the activities of other living beings; something which we quite often forget. For example, the increase in the concentration of oxygen in the atmosphere over millions of years came about as the result of the increasing number of photosynthetic microorganisms[5].

As is well known, farming began independently in different places around the world about 10,000 to 8,000 years before the present era.

The need to produce food for an increasingly larger population and industrial development are two factors that explain why the environmental impact caused by humans has increased so much since the middle of the 19th century. However, in addition to the quantitative aspects to be taken into account in assessing this impact, the historical and geographical circumstances, and above all, the state of science and technology are also extremely relevant. For example, when Thomas Malthus wrote his famous book *An Essay on the Principle of Population* (1798), famines were a frequent feature of European life. At that time, some 2 hectares (ha) were needed on average to produce enough enough to feed one person for a year[6]. As a result of the enormous increase in population between the end of the 19th century (1,260 million in 1850) and the middle of the 20th century (some 3,000 million by 1960)[7], the cultivated surface area at the latter time was 5 times greater than 150 years before. This increase in farmland necessitated breaking-up of large stretches of natural habitats and forests. At present, and even though world population has doubled - standing at nearly 6,000 million –, as a result of the application of scientific knowledge and the development of farming technology, the food needed for each person for a year can be produced in an area of under 0.2 ha.

Broadly speaking, some of the main milestones in the development of conventional agronomic practices during the course of the 20th century are summarised in the following table (Table 1):

Table 1.- Some milestones in 20th century farming

Date	Event
1908	Fritz Haber and Carl Bosch manage to chemically synthesize ammonia (using atmosphere nitrogen), thus enabling the development of nitrogen fertilisers.
1929	Economic depression in the USA.
1939	Paul H. Muller discovers the insecticidal properties of DDT (a compound first synthesized in 1874).
1944-1954	Dr. Norman Borlaug worked at the CIMMYT (Mexico) on developing high-yield, blight-resistant wheat.
1956	Mexico becomes self-sufficient with respect to wheat production.
1968	Pakistan becomes self-sufficient with respect to wheat production.
1970	Dr. Borlaug receives the Nobel Peace Prize for having developed high-yield wheat and thus notably reducing starvation in the world.
1974	India becomes self-sufficient with respect to cereal production.
1960-1980	Period approximately covering the Green Revolution in Asia and Latin America.

Adapted from F. García Olmedo. 2009. El Ingenio y el Hambre. Crítica, several pages.

In general, agronomic practice prior to the 20th century could be considered as "organic" because synthetic chemical products were not used to protect crops against pests, insects or weeds. The use of nitrogen fertilisers did not become widespread until between the two world wars. At the beginning of the 1920's, farming production fell considerably in the USA due to a serious, prolonged drought that linked with the 1929 crash[8]. These circumstances promoted research and the development of tools and techniques that could avoid, or at least alleviate, such situations. In 1939 Paul H. Muller discovered the insecticidal properties of DDT. As a result of its effectiveness in controlling a large variety of insects harmful for agriculture and considerably increasing yields, its use quickly extended. After World War II, nitrogen fertiliser production and agrochemical compounds increased substantially, creating the conditions for the Green Revolution of the 1960's and 1970's[9].

During those years, grain production, particularly that of wheat and rice, increased spectacularly in some developing countries, such as Mexico, Pakistan and India, as a result of the varieties of the blight-resistant (fungal disease that causes great crop losses), dwarf wheat developed by Norman Borlaug (1914-2009) at the International Corn and Wheat Improvement Centre (CIMMYT) in Mexico between 1944 and 1954. Some years later, Borlaug and his team obtained high-yield rice. Mexico, which in 1944 imported 60% of the wheat it consumed, became self-sufficient in 1956. Pakistan followed suit in 1968, while India managed to produce all the cereals it needed in 1974, witnessing a production increase from 12.3 million tonne in 1965 to 20 million in 1970. World grain production in 1960 stood at 692 million tonne and reached the figure of 1,900 million in 1992 in a surface area that had only increased by 1%[10].

The Green Revolution of the 1960's and 1970's brought a halt to the destruction of natural habitats that had come about in the preceding decades by multiplying crop yield by three[11]. It is estimated that over 1,000 million people were saved from starvation over those years. For that very reason, Dr. Borlaug received the Nobel Peace Prize in 1970. To date, he is the only Nobel Prize Laureate to have received his prize for innovations in agriculture, in spite of the fact that over 70% of the world population makes its living on it.

The spectacular increase in crop yields brought with it a 97% increase in irrigated farm land, along with increases of 638%, 203% and 854% in the use of nitrogen and phosphorous fertilisers and in the production of pesticides (insecticides and herbicides), respectively. World population doubled between 1961 and 1999, reaching a figure of 6,000 million. Nevertheless, in spite of this large population increase, farm land around the world only increased by 12%, while the surface area used for pastures rose by 10%[12].

With a current world population of some 6,500 million - 1,000 million of whom are suffering from hunger - we are, at present, using approximately half of the best quality land available around the world for intensive farming purposes and cow and sheep grazing[13]. The World Food Programme has recognised that the 2009 harvest will not suffice, even remotely, to help those people, while the outlook for the future is not very promising. World population continues to grow. It is estimated that it will reach over 9,000 million by 2050. By then, we would need to double food production at least.

Does this involve using more land? Not necessarily. In line with the data we pointed out for Malthus's time, one of the keys is the yield obtained for each hectare. As in previous times in history, the development of new farming practices and technologies will enable the maximisation of food production, in such a way as to reach a sufficient yield without any need to excessively increase the area under cultivation. Equally important is that the production and distribution of this sufficient amount of food be shared out fairly among the world population.

1.2.- Nature and us: responsible protection

Van Rensselaer Potter already developed the idea of a Global Bioethics, as described by Lecaros[14], placing the challenges of the survival of mankind in his environment at the centre of his concerns, but without loosing sight of biomedical problems. As we have pointed out above, for Palacios Global Bioethics must guide the use of science and technology to promote the development of societies, reconciling respect for human dignity with respect for the environment and other living beings[15].

Up until quite recently, western tradition considered humans to be at the centre of nature, the result being that their ethical concerns were wholly anthropocentric[16]. Non-human, living beings and nature could be used as instruments for the benefit of humans, without having to concern themselves about how their actions influenced, for better or worse, the development and even the extinction of other non-human, animal and plant species.

Greatly influenced by the ecologist movement, since the 1960's a profound change came about in the dominant view and new concepts appeared such as "environment quality" and "satisfaction", that went beyond the mastering-of-nature argument, and that of unlimited economic development[17]. Environment quality began to be considered necessary for entertainment and leisure activities.

At present, we can distinguish at least two stances concerning the relationship of humans with nature:

- *Biocentrism,* which centres its moral consideration on all living beings equally, because it understands life to be of value in itself[18]. People are held to possess the same dignity and rights as all other living beings.

- The ethics of *responsibility,* proposed by Hans Jonas[19]. The human being, on interacting with nature and altering it, is no longer the conqueror of all that exists on the planet earth, and becomes just another member of this community of living beings. Moreover, as a result of their intellectual capacity humans are responsible for all other living beings that inhabit their surroundings.

The Advisory Committee on Ethics in Scientific and Technical Research puts forward the following five basic ethical principles which, in our opinion, develop the ideas of the ethics of responsibility[20]:

1. Not to harm human beings.
2. To positively benefit human beings, both in terms of present and future generations, effectively encouraging their development possibilities.
3. To take into account, through dialogue, all human beings affected by regulations when it comes to making decisions about these regulations.
4. To equally distribute the burdens and the benefits, taking as a point of reference the ethical level reached by the corresponding society. This is particularly important in the case in hand regarding relations between developed and developing countries.
5. To take responsibility for nature. As we have pointed out, it is becoming increasingly more specific through the obligation to work towards sustainable development.

The first four principles are based on the acknowledgement of the dignity of the human being, whereas the last one points to the relationship between humans and all other living beings. This relationship cannot be one of predation and pillage, although at the same time it recognises that the survival of the human species depends on other living beings. Respect for nature does not mean, as Masiá so rightly says, that nature –other living beings- has to be kept as it is, but rather that we can modify it without destroying it; we should use the best and least pollutant technology, or a combination of the technologies most suited to solving the problems in question[21].

Respect for human dignity, the basis of all ethical considerations, leads us to assuming responsibility for all those people who need help to survive. As we have mentioned above, at present there are over 1,000 million people - approximately one in six – who are suffering from malnutrition, and all too often, end up starving. Figure 2 shows a map of extreme hunger in the world: Sub-Saharan Africa, Central American and some Asian countries.

Figure 2.- Map of extreme hunger in the world.

Taken from the FAO report "*The Sate of Food and Agriculture. Biotechnology: Meeting the needs of the poor?*" (2003-2004).

It is true that the percentage of the under-nourished population dropped substantially in most parts of the world between 1969 and 2001, being on average somewhere between 10% and 15%. Nevertheless, in 2003 in Sub-Saharan Africa the figure remained steady at around 33%, practically the same as back in 1969[22].

Poverty causes malnutrition, hindering or making it difficult to access food. Moreover malnutrition of itself has a decisive influence in a person's state of health and life expectancy. In 2000, the 192 member countries of the UN agreed to make a concerted effort to achieve the Eight Millennium Development Goals in 2015[23]. The first of these is to "eradicate extreme hunger and poverty".

We believe that the production of food must be part of the *Ethics of Responsibility,* both as regards the use of modern biotechnological applications, and specifically genetically modified seeds and with respect to food produced by organic (or conventional) farming techniques.

Following the same ideas expressed by Palacios in Global Bioethics and Jonas in the *Imperative of Responsibility,* which we have mentioned above, the European Group on Ethics in Science and New Technologies in its recent report on the ethical implications of modern developments in farming technology, studies them in the light of the following priorities:

- Food security[24]; that is to say, the availability (which implies physical and economic accessibility) of different foods in sufficient quantity and nutritional quality to enable all humans lead an active and satisfactory life.
- Safety of food: that is, that the food be healthy, non-toxic and fail to cause health problems for consumers.
- Sustainability of the production methods, also taking into account food transport and distribution.

The first two priorities are included in the concept of human dignity, while the third one considers human responsibility as regards other living beings.

1.3.- Sustainable development, sustainable farming, sustainable food: What do we mean by these concepts?

1.3.1. Sustainable development

The most well known definition of sustainability is perhaps that of the Brundtland Report (World Commission 1987)[25] which extended the concept of sustainability to all activities that lead to the development of a society:

"*consists in meeting the needs of the present without compromising the ability of future generations to meet their own needs*".

This report represents the evolution of an approach that began to take shape in the 1970's. Back then, various groups of experts published writings denouncing the prevailing development models of the time as unviable. Among these, the Meadows Report entitled *The Limits to Growth*[26] stood out.

By applying this to food, and bearing in mind the two aspects of the *ethics of responsibility,* we will distinguish two facets of sustainability that are intimately linked to each other:

1. The sustainability of food as such,
2. the sustainability of the production methods employed.

The first point refers to the responsibility towards present and future generations, and covers two main aspects:

- The safety of the food for the consumer, and its nutritional and sensory quality;

- Its security or accessibility, not only as regards the amount required to meet the energy and nutritional demands of the world population to lead an active and healthy life, but also with respect to people's food preferences[27].

The second point refers to the responsibility towards non-human living beings and the environment. It includes production aspects such as the use of agricultural land, water and agrochemical compounds and their effect on animals and on polluting water resources, the maintenance of the top soil to avoid its erosion, different agronomic practices, etc.

Even though we have not expressly mentioned it, the economic facet is also inherent in both points, because this will enable the farmer to improve her standard of living, which, in turn, will enable the development of local socio-cultural systems. The development of local socio-cultural systems is one of the aims promoted by organic farming within the framework of its philosophy[28]. The lack of a generational turnover in most rural sectors as a result of the younger generations migrating to cities, provoked, among other things, by an extremely limited economic return, is unfortunately very widespread[29].

A recent study carried out in the Netherlands[30] on a diverse group of farmers (men and women with conventional, organic and other farming practices) shows that the economic return is very important to all of them, though the greater or lesser emphasis on this aspect depends on the individual's level of idealism. The importance given to social sustainability (poverty reduction, fair trade, fair prices) and responsibility to the ecosystem varied quite a lot, with organic farmers in general tending to highlight these issues. Aiken[31] extends economic return to all sectors involved in food production, starting with farmers, but also seed producers, farm machinery makers, manufacturers of agrochemical products, etc.

The concept of *sustainability* can have different nuances depending on the body or organisation that is defining it. As described by Clonan and coworkers[32], the organisation "Sustain: Alliance for Better Food and Farming" includes social, environmental and economic components. For them, sustainable food is healthy, accessible, nutritional, environment and biodiversity friendly, encourages fair trade practices and respects the rights of workers throughout the food chain. However, nutritionists highlight the healthy and nutritional aspects of food, whereas the Soil Association (UK Organic Farms Association) promotes the production of food without the use of chemical pesticides and the Free Trade Association emphasises fare trade practices.

1.3.2.- Sustainable farming and food

For its part, the Spanish Institute of Sustainable Agriculture, integrated in the Consejo Superior de *Investigaciones Científicas* (Council of Scientific Research)[33], dedicated primarily to Andalusian farming systems, basically highlights production and environmental aspects:

"*…means efficient and stable farming production, with a special commitment to production quantity and/or quality, which preserves the natural resources of farming systems and reduces the negative impact of agriculture on the environment*".

The *Keystone Alliance for Sustainable Agriculture* goes one step further holding that sustainable farming not only meets present needs, but also, improves [the italics are ours] the ability of future generations to meet their own needs. To this end it proposes:

- Increasing agricultural productivity to meet future nutritional needs, while at the same time decreasing its impact on the environment, including water, soil, habitat, air quality and climate emissions, and land use;
- Improving human health through access to safe nutritious food, and
- Improving the social and economic well-being of agricultural communities"[34].

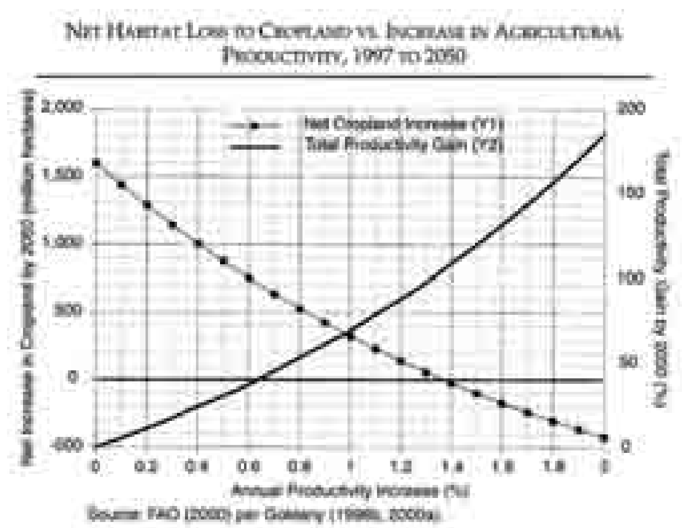
Over recent years, the importance of crop productivity (or yield) has been emphasised in conventional farming, including the use of genetically modified seeds, but crop productivity is seldom mentioned with respect to organic crops. Whenever it has indeed been mentioned, it has often been done negatively, as if productivity were only important for a society exclusively interested in economic progress, without caring for the quality of life of its inhabitants, the nutritional quality of their food, or the health of this planet[35].

Even though this has been the case in many production sectors, including that of food production, in our opinion, crop productivity is a basic feature of sustainability of any farming system for several reasons. On the one hand, it directly affects the improvement of human health, because it depends on food availability to a great extent. On the other hand, increased productivity also provides the farmer with a greater economic return, which, in turn, contributes to improving the living conditions of rural communities.

Moreover, low productivity implies the ploughing of additional quantities of land to obtain the same amount of food, something which would have extremely negative consequences for animal and plant biodiversity due to the destruction of habitats, thus compromising sustainability. In this sense, in 1997 Goklany studied the impact that crop productivity could have with respect to the amount of land needed to feed a population which, at that time, it was believed would reach 9,000 million in 2050[36]. Figure 3 shows the results of his study.

If average crop productivity in 2050 is the same as in 1997, the total increase in food production will have to come from the increase in the land farmed, which will have to double, adding a further 1,600 million ha to the already 1,500 million ha being used for this purpose. This would involve an enormous loss of ecosystems along with the corresponding loss of biodiversity. If, on the contrary, productivity were to increase by 1.4% every year, there would be no need to increase the land being farmed, whereas if it were to increase by 2% per year in that period of time, over 400 million ha could "be returned" to nature and natural habitats recovered.

• Figure 3.- The net habitat loss due to increasing farmland as a function of the annual increase in agricultural productivity between 1997 and 2050.



Taken from I Goklany. 2001. The Precautionary Principle. Cato Institute, Washington.

The multinational company Bayer points to a different aspect of the concept of sustainability on its web page[37]: "sustainable agriculture must strike a balance between commercial success, environmental responsibility and social acceptability" (our italics). Even though the multinational does not specify what it understands by social acceptability, we assume it refers to the production of food that a particular community considers to be suitable and acceptable, because no food can be imposed on any sector of the population without its knowledge and its consent. This concept involves the production of particular food items in different communities.

Muñoz[38] also highlights the importance of producing more food on less land, making good use of land and water and reducing the use of pesticides and herbicides. Furthermore, he adds that:

"this process must not overlook the fact that the world's food problems are not simply a result of production problems, but rather social questions concerning availability, acquisition power and distribution must also be taken into account".

In our opinion, this statement highlights, among other things, the importance of food production *in situ,* that is to say, wherever it is most needed, because food distribution is not easy in countries or regions where roads and other transport infrastructures are deficient or simply not available, as for example in Sub-Saharan Africa[39]. Wherever the distribution of foods produced elsewhere fails, food security also fails as does the power to acquire food, because distribution tends to increase its price. Food importation, an apparently easy solution, would increase rural unemployment in countries in which the security of over 60% of the families depend on agriculture for their living[40].

Moreover, *in situ* food production by small and industrial farmers exerts a very positive effect on the development of local communities by increasing farmers' incomes, job creation and the reduction of dependence on other countries. It also avoids long distribution channels, which in turn reduce energy consumption for transportation. According to recent declarations made by the Director of the FAO, "The challenge is not only to increase global, future production, but to increase it where it is mostly needed and by those who need it most"[41].

The same line of reasoning is taken in the recent report by the UK's Royal Society report, "*Reaping the benefits: science and the sustainable intensification of global agriculture*"[42], which emphasises that if agriculture must contribute to the disappearance of poverty, technologies must be studied to increase production in their specific social and economic contexts, as well as in the wider context of their acceptance by the community.

We fully agree with the words of García Olmedo:

"If we wish to feed an increasing number of humans in the future, we will have to produce more per hectare, even if we reduce the amount of meat products in our diet; and, secondly, we will have to produce in a cleaner fashion. Agriculture has been against the environment since its invention, over 10,000 years ago now. Indeed, the more primitive it has been, the more it has worked against the environment. In the current debate, the fact that there were innumerable farming cultures that declined, or became extinct because they were not sustainable, has been either overlooked, or hidden. To ensure the sustainability of the current farming system, which is under serious threat, specialised research must be given priority, as must the practical application of current knowledge[43]".

The UK's Royal Society report just mentioned above acknowledges the pressing need to increase global food production to cope with the foreseen population increase by 2050, without increasing the amount of cropland. It insists that this must be achieved without doing any more harm to ecosystems and without the excessive use of non-renewable resources. It introduces the concept of "*sustainable intensification*" into large scale global farming in which productivity is not to be exclusively measured by yield per hectare, but also by yield per non-renewable resource used. This concept is also used in agroecology. They come to the conclusion that we are facing an enormous challenge, so no technology or farming system can be discarded.

1.4.- From controversy to constructive debate to promote more sustainable food production

In line with many of the opinions we have presented above, we believe that sustainable food production must take into account three basic aspects or pillars in the pursuit of its goals:

- Social justice and community acceptability:
  - Accessible food in quantity, diversity and quality, both nutritionally and sensorially.
  - Food production *in situ* to favour its accessibility to the local population and to promote the development of local communities.
- Economic return:
  - Improvement in crop yield.
  - Fair prices instead of farming subsidies.
- Respect for the environment:
  - Reducing the amount of agrochemical products, water consumption, energy consumption, CO_2 emissions and that of other greenhouse effect gases, soil erosion.
  - Not increasing cropland.

Taking these basic pillars into consideration, we will analyse the contribution that plant food production by organic procedures or through the use of genetically modified seeds makes to sustainability.

CHAPTER II: ORGANIC FOOD

2.1.- Historical aspects of organic farming

We already pointed in the previous chapter to the fact that, to a certain extent, all agriculture before the 20th century could be considered "organic", because no other fertiliser, apart from animal manure, was used. Moreover, there were no synthetic pesticides and farmers planted their own seeds, or at most, shared them with others who lived nearby. Nevertheless, the concept of "organic farming", came into use in the 1960's by a group of authors that initially questioned the use of insecticides in farming. The abuse of chemical products in farming, along with its subsequent polluting of ground water and the presence of pesticide residues in food[44] led a part of the population to reject agronomic farming practices known as *conventional*. Proposals, principles, methods, techniques and tools that became known as *organic farming* were proposed, in an attempt to distance themselves from tools and techniques considered to be harmful for the environment.

Silent Spring (1962) by Rachel Carson, a scientist in the U.S. Fish and Wildlife Service, is considered by many writers as the most influential book of the second half of the 20th century. In it she described the negative effects of pesticides on nature, as well as on people. As a result of the prestige enjoyed by the author due to her books on the sea[45], *Silent Spring* exerted a big influence on high-level members of the American government who began to pay attention to the idea that ecological processes are important to all forms of life[46]. Eventually this gave rise to the setting-up of the Environmental Protection Agency in 1970, and to the prohibition of the use of DDT in farming in 1973[47]. The message taken up by her readers was that chemical products and the industrialisation and technification of society were harmful to nature.

Even today, the idea is still widespread that that all "natural" things, all that is found in nature, is harmless or even beneficial both for our health and for the environment, whereas that which is artificial or synthetic is bad and harmful. This is completely wrong: there are numerous examples of natural compounds produced by plants, animals and microorganisms that are toxic[48]. By the same token, there are plenty of examples of synthetic compounds that help us to preserve our food, among other things. The effect that vitamin C (ascorbic acid) has on the organism depends on its chemical structure, and not on whether it is synthetic or comes from fruit and vegetables, for example.

In the 1970's several American states passed the first laws regulating organic farming.

2.1.1.- Types of farming

There are many classifications of farming practices, depending on the use of materials, the type of tilling practiced, the size of the farm, etc. For the purposes of this paper we define the following terms taken from the glossary of the University of California at Davis[49]:

- Organic farming/agriculture: this is basically characterised by the non-use of synthesised chemical products (such as pesticides) or soluble fertilisers, only using manure and natural pesticides. The labelling of organic food and food products is regulated by law in Europe[50], and by the National Organic Program standards of the United States Department of Agriculture[51].
- Conventional farming/agriculture: system of industrialised agriculture, characterised by mechanisation, single crops and the use of materials such as fertilisers and pesticides. It gives great emphasis to yield and return.
- Conservation tillage: this is characterised by minimal tillage work, holding on to at least 30% of the remains of the previous harvest in order to minimise soil erosion and to maintain organic matter[52].

As far as the use of synthetic pesticides and fertilisers is concerned, organic and conventional farming (according to this definition) represent the extreme ends of a continuum of farming practices which, ultimately, depend on the size of the farm, on local conditions, and on the type of crop, among other aspects. In other words, there are "conventional" farming practices that use crop rotation; manure and compost as fertilisers; integrated pest control; pesticides and soluble fertilisers, whenever necessary; non-tillage or low tillage practices; etc. Likewise, some farming practices are difficult to distinguish from those of an organic nature, because they employ the same methods or technologies, but do not meet the legal regulations to enable the labelling of their products as organic. In order to avoid confusions between these other “low intensity” farming practices and certified organic farming, when we refer to organic farming in this paper, we will only consider papers and publications that deal with products carrying organic labels.

2.2. - Characteristics of Organic Farming

Organic farming is a way to produce food that is, in principle, less aggressive for the environment, and which seeks to find a balance between food production and environmental protection. This implies a profound change in agronomic practices, substantially reducing the use of energy and resources, both in the production of the materials required (such as fertilizers) and in the use field machinery[53].

Organic farming uses production methods that improve the stability of soil ecosystems, maximising the recycling of nutrients and diverse production.

In addition to these aspects, which are directly related to respect for the environment and which emphasise minimising the damage that can be caused by food production, for many people and groups organic farming goes beyond these environmental issues by insisting on encouraging local food production adapted to the socio-economic and environmental setting. It highlights the relation between people and food production resources and seeks to reduce costs and increase the economic viability of small and medium-sized farms. This aspect, however, refers to a particularly wide aspect of agricultural sustainability, in which the well-being of present and future generations is also considered. In this sense, it could be considered more as a philosophy of life[54] than as merely a manner of producing food. Figure 4 summarises the different aspects of organic farming in this broad sense.

Figure 4.- Objectives of Agroecology

Taken from J Briz (co-ordinator). 2004. *Agricultura ecológica y alimentación*. Fundación Alfonso Martín Escudero, page 19.

The text of the 1st Whereas Clause of the European Regulation on organic production and the labelling of organic products[55] also leads one to believe that organic farming is something more than merely a manner of food production:

"Organic production is an overall system of farm management and food production that combines best environmental practices, a high level of biodiversity, the preservation of natural resources, the application of high animal welfare standards and a production method in line with the preference of certain customers for products using natural substances and processes. The organic production method thus plays a dual societal role, where, on the one hand, it provides organic products for a specific market that responds to consumer demands, and on the other hand delivers public goods contributing to the protection of the environment and animal welfare, as well as to rural development."

This text clearly states that organic production is aimed at “certain customers” that prefer products obtained by natural processes. Therefore, it represents a break with the idea of an average European customer, representative of the whole EU (the idea that we are all consumers) for whom laws are enacted and whose health is to be protected.

The fact that this regulation protects a manner of production preferred by some consumers, based on natural substances and processes, immediately suggests two ideas to us: 1) that this consumer group is considered in some way 'superior' to the rest, so it receives special treatment by protecting its preferred form of food production; and 2) that the rest of the food produced in a different way is of less quality. Whatever the case, we do not believe this to be very fair.

2.2.1.- Pest and weed control

In the light of the foregoing, we will restrict ourselves to the procedures that have been approved by the above mentioned European regulation.

A "weed" is defined as a plant which grows in a particular place, or at a particular time, that interferes with the concrete and specific interests of humans. It is, therefore, an anthropological and not a biological concept. From the farming perspective, there are some 250 species considered to be "weeds", as long as they are to be found growing in places where they are competing with farm crops for soil nutrients and water.

According to R. Labrada Romero, the FAO expert on weeds, the latter are the farmer's main natural enemy[56], giving rise to losses of some $95,000 million in world food production. These losses are equivalent to 380 million tonne of wheat, half the world’s expected production for 2009. Overall losses due to pathogens and insects are estimated to cost some $85,000 million and $46,000 million dollars, respectively.

Because weeds can also serve as a refuge for organisms that affect crops, productivity improvement must necessarily include improvements in weed management. Therefore, the main objective in handling weeds is to manage the crop/weed ratio favouring the growth of the crop. Because organic farming rejects the use of synthetic pesticides, it employs different pest control strategies[57]:

- Preventive methods: quality of the materials used (certified seeds, compost and substrates), improved drainage,...
- Cultural methods: crop rotation, crop combination, cover crops, planting dates, fertilisation control, crop density, fallow land and the use of the previous year's crop residue.
- Biological methods: use of insects and fungi.
- Physical methods: manual removal, field tillage (light, without turning), thermization.
- Chemical methods: use of prepared materials based on mineral products to modify soil pH.

Weed control can be extremely specific, depending on the crop in question, on the climate, on soil characteristics and on the weed species present in each area. Some of these techniques also combine with other more specific pest control ones.

Crop rotation and fallow practices reduce soil fatigue, favour organic residue decomposition and improve land fertility.

In addition to these cultural methods to control insects and diseases, organic farming also uses different procedures (Annex II to the above mentioned European Regulation):

- Organic chemical compounds of animal or plant origin: azadirachtin, rotenone, pyrethrins, pyrethroids such as deltamethrin and lambda-cyhalothrin (only in traps), pheromones (only in traps), vegetable oil and quasia extracts.
- Microorganisms: the bacterium *Bacillus thuringiensis* has been used in spray formulations since the middle of the 20th century.
- Microbial products: spinosad is a mixture of chemical compounds produced by the soil-dwelling actinomycete *Saccharopolyspora spinosa*.
- Inorganic compounds: various mineral salts including copper compounds, potassium permanganate, aluminium sulphate, potassium sulphate, sulphur, and potassium salts of fatty acids.

Practically all of these products, which are obtained from plants and microorganisms, and some inorganic compounds, are powerfully toxic for many animal and/or plant species. Indeed, they are also used in applications other than organic farming. For example, spinosad is extremely toxic for bees and rotenone is used as a rat killer. Excess copper is related to neuro-degenerative diseases such as Alzheimer's[58].

2.2.2.- Soil fertility

In addition to being the substratum in which roots develop and which supports the plant, soil is a complex system where organisms (animals, plant and microorganisms) that are present interact with the physical and chemical medium in which they live. It is a mixed, organic and mineral medium capable of holding a certain amount of water and is influenced by the metabolic activity of the organisms it contains. Soil provides the growing crop with nutrients and water. Depending on its different components, a particular soil can be more or less suited to grow certain crops. Moreover, it will need to be conditioned.

Regardless of the size of the farm, soil management constitutes the basis of productivity and ensures farm continuity. Soil machining should not reach its deeper layers in order to safeguard water and air preservation.

Fertilisation returns to the soil nutrients that have been extracted with each crop, being organic matter the base of the fertilisers used. This organic matter comes from recycling different products that must be composted before use.

Generally speaking, the management of soil fertility in organic farming is based on three complementary actions[59]:

- boosting soil biodiversity.
- increasing nutrient availability.
- reducing soil degradation due to direct loss, to pollution, or to elimination of its biodiversity.

The already mentioned European regulation explicitly prohibits the use of highly soluble fertilisers. Consequently, organic farming uses other products to return to the soil the nitrogen required by crops. Annex I to this document lists the following, among others:

- animal manure (from organic livestock farms and in amounts under 170k/ha per year, depending on the amount of nitrogen in the soil).
- liquid animal excrement.
- solid farmyard manure such as hen droppings.
- composted or fermented domestic waste (plant and/or animal).
- sub-products of animal origin: blood flour, fish, meat, feather; hoof, horn, bone dust; dairy products; hair and skin agglomerates; wool.
- sub-products of plant origin: oil-yielding cakes from oil crops and wine cellar residue.
- seaweeds and seaweed products.
- various inorganic compounds and mineral salts (referred to above).

In addition to these particular products, so-called “green fertilisers” are also used. These are legume crops that are mixed in with the soil in order to provide organic matter, nutrients and nitrogen. To this end, every 2-3 years these legumes are grown, or the land is left fallow, ploughing the residue into the ground afterwards.

There is an extensive range of interrelated factors that both the organic and the conventional farmer must take into account when managing his farm, such as geographic location and the size of the farm, rainfall rates, wind and temperature data at different times of the year, soil type and its quality, the crop, the type of pests, weeds and diseases present, his formal education, and in short, his practical experience, among a host of other elements. The amount and type of synthetic products that he will have to use will vary greatly throughout the season, and from one season to another[60].

Due to the low mechanisation and the lack of use of synthetic chemical products, when these aspects are taken into account in calculating yield per unit of energy consumed, organic energy costs are significantly lower than those of conventional farming systems[61]. Cultural practices favour soil fertility and increase its water retaining capacity. We consider all these to be the most noteworthy positive environmental factors related to organic farming.

2.2.3.- Other considerations

We have mentioned the fact that organic farming also takes into account socio-economic questions that are conducive to the development of rural farming communities and that encourage relations, preferably directly, between food production resources and consumers. Nevertheless, in more developed countries, the recent rise in organic farming, particularly of processed organic food, has attracted the attention of multinationals that contract the production of organic food and raw materials, transforming them into processed organic food, packing them and supplying big supermarket chains[62] (See Table 2).

Table 2.- Organic product companies bought out by big multinationals in the United States and Canada.

Multinationals	**Organic product companies**
Colgate-Palmolive, Inc.	Tom's of Maine – natural personal care products
Kraft Foods, Inc. (member of the Altria Group, also owners of Phillip Morris, Inc.)	Back to Nature – organic cereals
Coca-Cola	Odwalla, Inc. – juices and nutritious organic bars
Loblaw Companies, Ltd. (Superstores supermarkets in Canada)	Its own President's Choice Organics line which markets over 300 products
Dean Foods (main US dairy company)	Horizon Organic
General Mills,	Small Planet Foods (owner of Cascadian Farm: Frozen fruit and vegetables, energy bars)
Kellogg's	Kashi Cereal, and Morningstar Farms
Wal-Mart, one of the main food distributors in the USA	Plans to become the main supplier of organic food

Adapted from Ronald y Adamchack, 2008. Op. cit.

Many certified organic food items are being grown in Africa in recent years due to the fact that the agriculture on the African continent has used very few synthetic chemical products because of the poverty of its farmers. Consequently, it is quite easy to convert traditional farming practices into organic ones. Nevertheless, practically all certified organic production is exported, mainly to Europe. Frequently, crops such as avocado, cocoa, coffee, tea, fruit and vegetables are grown on large, specialised farms, certified as "organic" operations and located near airports[63].

The distribution of organic products over long distances by air, mainly from developing countries, has been considered contrary to the organic farming philosophy presented above, to the extent of not receiving the organic label. The reason was that in addition to having production far removed from consumers, plastic packing of dubious recyclable properties must be used, not to mention the excessive contribution to the increase of CO_2 emissions. In spite of the fact that they continue to use these both in their transport and marketing, the British Soil Association, which regulates the production of organic food in the United Kingdom, decided in January 2009 that organic food imported by plane over long distances could carry the organic label because it said it was prioritising its contribution to improving the living conditions of farmers in developing countries[64]. Nonetheless, it seems that the poor rural population benefits very little from these organic crops[65].

This industrialisation of farming and of organic foods, even though it may respect legal production standards and regulations, would end up destroying, or at least significantly reducing, that nearness between producers and consumers, as has already happened to a large extent with intensive conventional farming.

2.3.- Legal regulation of organic farming

The impact of legislation on how organic farming is perceived has been and continues to be very important. Trying to offer consumers a guarantee of the meaning of the “organic” label, regulations in some countries lay down criteria as to what may, or may not, be taken into consideration for a product to be deemed worthy of carrying such a label.

Ultimately regulations determine which products can be labelled as organic, or not. Of the three criteria we pointed to in Chapter 1 as the “pillars” on which to argue for food production sustainability, we will see that only some aspects of the third one (reduction of the environmental impact) are considered to be determining factors for the labelling, or certification, of organic products.

Organic farming practice is regulated in Europe pursuant to aforementioned Council Regulation (EC) No 834/2007 and to Commission Regulation (EC) 889/2008[66] which establishes the application provisions for the former. The latter document specifies how to grow organic plant food and how to produce organic food of animal origin. Both documents state the conditions in which it is possible to grant a crop, or food of plant or animal origin, the right to employ expressions such as "eco", "organic" or "bio" on its label and in its advertising. It is, therefore, a regulation that only provides for production methods and how these must be controlled, but does not provide for the quality of the product that is obtained. Even though Article 3 of Regulation 834/2007), which states the aims and principles of organic farming, specifically refers to "producing products of high quality", in no other place in this regulation the term "quality" is defined.

Essentially, for a food to be able to carry an organic label the guidelines we have given in the previous section must be followed, particularly those referring to the control of weeds and pests and to the maintenance of soil fertility. Only the use of products and microorganisms specifically cited in Annexes I and II are permitted. The use of synthetic pesticides and soluble nitrogen fertilisers is strictly prohibited. This modus operandi closes the initial debate because it eliminates socio-cultural and economic components, focusing on environmental ones alone.

According to Article 3 of Regulation 834/2007:

"*Organic production shall pursue the following general objectives:*

a) Establish a sustainable management system for agriculture that:
- *1) Respects nature's systems and cycles and maintains and enhances the health of soil, water, plants and animals and the balance among these;*
- *2) Contributes to a high level of biodiversity;*
- *3) makes responsible use of energy and the natural resources, such as water, Soil, organic matter and air;*
- *4) Respects high animal welfare standards and in particular meets animals' species-specific behavioural needs;*

b) Aims at producing products of high quality;

c) Aims at producing a wide variety of foods and other agricultural products that respond to consumers' demand for goods produced using processes that do not harm the environment, human health, plant health or animal health and welfare".

Nowhere in Regulation 834/2007 is it suggested that food produced in accordance with its specifications is of a higher nutritional or sensorial quality than that which is produced by other methods, whether conventional or genetically modified. The terms that must be included on the label exclusively refer to production methods (Article 23). Nevertheless, previous European Regulation concerning the production of organic food, derogated on 1st January 2009, explicitly stated in Article 10.2 that "no claim may be made on the label or advertising material that suggests to purchaser that the indication shown in Annex V [that the products have been subject to a control system] constitutes a guarantee of superior organoleptic, nutritional or health quality"[67].

For processed foods, 95% of the ingredients (by weight) must be organic in order to indicate such a characteristic on the label, accepting, therefore, that 5% of the ingredients are not organic.

To the best of our scientific knowledge, it is not possible to distinguish an organic food from a non-organic one (as long as the latter is not genetically modified) by analytical techniques, because there are no "marker compounds" associated exclusively with organic production. Consequently, the traceability of an organic food or ingredient is fully backed up by a paper trail: in documents that the farmer (or stock breeder) must hand over to the authorising control agencies in order to certify that such a food item, or ingredient, has been produced by authorised procedures. And, therefore, can carry the organic label.

The "organic" label, therefore, only certifies that the food in question has been produced in accordance with the standards established in the current Regulation.

Organic farming in the United States is regulated by the Organic Food Production Act described in Title 21 of the Farm Bill (1990)[68] which lays down the national regulations for the production of organic certified foods. To this end, the Department of Agriculture set up the National Organic Program. As with European legislation, American law certifies that the food has been produced in accordance with certain agronomic practices and by avoiding the use of prohibited agrochemical products. It also does away with the socio-economic and cultural component of the organic farming philosophy.

2.4.- Price and productivity: the Achilles heel of organic farming

In Chapter I we proposed three pillars on which to base sustainable production, the first of which referred to people’s accessibility to food, in terms of both quantity and quality (nutritional and sensorial). Crop yields need to increase for everyone to have enough food. This was acknowledged last year by the Director of the FAO, Jacques Diouf, due to the increase in food prices[69]. Moreover, in May 2009 the Director of the Department of Plant Protection and Production[70] stated, in reference to the need to double food production by 2050: "the world has no alternative but to intensify sustainable agricultural production".

The productivity of organic agriculture compared to that of conventional agriculture is an extremely controversial point with no easy solution because it depends, among other factors, on the crop being studied, the place, the type of crop used in rotation, the amount of manure per hectare, and on the crop cover to produce "green fertilisers". As a result of fallow practices and/or the growing of green fertilisers, productivity considered over several years is normally moderate, even though in a specific year it may be comparable to that of conventional farming. The results of comparative studies can be extremely diverse because it is very difficult to ensure that all of the most important factors are paired. Thus, Liebhardt gives yield figures of between 94% and 97% for conventional operations for corn, soya and wheat over the 1990's[71]. However, other researchers from the experimental farm at the University of California at DAvis obtained an average yield for organic corn of 66% of that of conventional corn over a 9-year period[72].

Recently, Badgley and coworkers[73] carried out an extensive study of 293 cases in which the yields of different crops using organic and conventional production methods were compared. They conclude that the average yield ratio (organic:conventional) is slightly less than 1.0 in the studies carried out in developed countries, and over 1.0 in developing countries. In accordance with their findings, they propose a food production model using organic production methods that would provide enough food to sustain the current world population, without increasing the land currently used for this purpose. Even though the results of this analysis seem to be quite promising, we feel that the study has the following methodological errors that are of sufficient importance to invalidate its findings.

Firstly, the authors indicate that they have included the results of different crops in their study: crops that carry organic certification, and others produced by non-intensive, or low intensity, production methods. According to their description at the beginning of the article, they define "organic" crops for the purposes of the study as those that use crop cover, manure, compost, crop rotation and biological pest control, including a limited use of synthetic pesticides and soluble fertilisers, without taking into account whether these are "certified" organic crops, or not. As we have stated above, these agronomic practices are used on a lot of conventionally produced crops that are not necessarily certified organic, along with variable amounts of agrochemical products.

Secondly, as explained by the authors themselves in the methodology section, they have not included pre-harvest losses in their calculations, arguing that they are not necessarily greater in organic systems than in conventional ones, because the former employ a variety of pest control methods. We believe that pre-harvest loss is a very important matter that directly affects crop productivity and economic viability and may be a decisive factor for the farmer when it comes to deciding whether to use one or the other farming practice. Finally, as pointed out by Goulding and Trewavas[74], a high percentage of their data on organic farming refer to experimental studies carried out in research centres, not on commercial farms. The correct way to make these comparisons would be to use the production data from a number of commercial farms in quite different areas in the country and over several years, because yield can vary by up to 4 times in two consecutive years[75]. Goulding and Trewavas provide a number of cases comparable to those of Badgley and coworkers in which the average yield ratio (organic:conventional) is 0.6 – 0.7 for wheat.

In a comparative study of organic and conventional farms over 21 years, Mäder and coworkers[76] found that the average yield of organic systems was 20% below that of conventional operations due to the fact that the nitrogen, phosphorous and potassium contribution in organic systems was between 34% and 51% less than that in conventional systems. Average organic potato yields decreased to between 58% to 66% with respect to the conventional potato yield as a result of the low potassium contribution and the effect of the pest Phytophtora infestans.

One of the main reasons for organic yield being lower than that of conventional farming is, in general, due to the ban on the use of soluble fertilisers. Legumes, in addition to manure, are grown for a year to use as "green fertiliser" over the next two years to provide the nitrogen needed by the soil[77]. During that time, the land is not in commercial production, thus explaining the low yield. For that very reason, even though in specific years yields may be comparable, when a period of consecutive years is considered, the organic farming yield can be some 20%-30% less. Though this lower yield may be tolerable in developed countries, it is a practice that farmers in developing countries cannot afford to follow[78].

As Trewavas explains (in the previously cited article), a crop's nitrogen need is not the same throughout all of its stages of development. In general, the greatest need for nitrogen occurs during the production and development stage of the leaves, the vegetative reserves of which are decisive for seed formation. Seed production is at its peak when the nitrogen contribution is synchronised with the crop needs during leaf formation. At this moment in time the plant needs to be provided with a high level of nitrogen in the form of soluble fertiliser. Nevertheless, the fertilisers used by organic farming procedures (manure, green fertilisers that consist of legumes that are ploughed under and low solubility minerals) release the required nitrogen constantly, throughout the entire season. Thus, when most needed, the plant has a limited amount of nitrogen. One option would be to increase the amount of manure, or mineral fertiliser, which would be applied to cover the needs at these specific moments in time. Nevertheless, as manure nitrogen is released constantly, high levels of nitrogen would be lost with water throughout the whole season, thus limiting the benefits of these types of fertilisers.

Another reason why organic farming yields are less those of conventional systems is due to the fact that chemical herbicides are not used. Uncontrolled growth of weeds in tilled fields is, after environmental restrictions, the main cause for the low crop yields. Crop losses lie between 15% and 90%, in extreme cases[79]. Whereas conventional farming preferably uses chemical weed killers, organic farming uses techniques such as crop rotation, cover crop, mechanical intervention (hoeing, manual weeding, tilling) and solarisation (to reduce the viability of seed germination) in order to reduce the amount of unwanted species.

In reference to the lesser yield of organic farming, the FAO Director stated on 12th October 2009 at the opening of the High-Level Forum on the future of food that "while organic agriculture contributes to hunger and poverty reduction and should be promoted, it cannot by itself feed the rapidly growing population without a sensible use of chemical fertilisers"[80]. In his opinion, "agriculture will have no choice but to be more productive", pointing out that "increases would need to come mostly from increased yields …rather than from farming more land".

2.5.- Rejection of genetically modified crops by organic farming

In 1996 the first genetically modified plants were released for commercial purposes worldwide. According to above mentioned Regulation 834/2007 on organic production, genetically modified food is that which is considered to be, *or to contain,* genetically modified organisms (GMO), along with that which, *although not containing GMO's, has been produced from these*. A genetically modified organism is any organism into which one or more genes from another species have been inserted, or which has had one or more of its own genes modified by genetic engineering techniques in the laboratory. That moment of the introduction of genetically modified crops in 1996, is also the date on which organic agriculture rejected head on the use of genetically modified seeds.

To a great extent, the definition of organic agriculture stated in these documents, especially in Europe, has played a key part in that opposition. Explicitly, the 9th Whereas Clause of the European Regulation on organic farming prohibits the use of GMO's in organic agriculture in the following terms:

Organic farming cannot use GMO's or products obtained from, or by, GMO's such as food, animal feed, technological aids, agrochemical products, fertilisers, soil conditioners, seeds, plant reproduction material, microorganisms or animals.

As a possible explanation of this position, it explains in the same Whereas clause that

"Genetically modified organisms (GMO's) and products produced from or by GMO's are incompatible with the concept of organic production and consumers' perception of organic products. They should, therefore, not be used in organic farming, or in the processing of organic products".

The only reason that one can gather from this supposed incompatibility, and one that is patently subjective, is that genetic modification does not fit in with the perception that the consumer has of what it means to be organic. Indeed, as we have already emphasised above, organic products are produced in accordance with "certain consumers' preferences", which leads us to think that the European Union legislator only takes a particularly specific group of consumers into account, the characteristics of which he does not specify.

It is difficult to come up with a scientific basis for this head on rejection of the use of genetically modified seeds in organic farming. We believe that this attitude is due to the idea, albeit false - but which is becoming increasingly widespread in society - that holds organic farming products to be *natural,* whereas genetically modified crops are the result of extensive laboratory manipulations. In addition, the unfortunate policy that European institutions and some regional governments have pursued with respect to genetically modified crops, passing legal dispositions in their favour but in practice hindering their use, has not helped any[81].

We deem it important to highlight the 3rd paragraph of Article 23 of the current European Regulation on the production of organic food (the underlining is ours):

The terms referred to in paragraph 1 shall not be used for a product for which it has to be indicated in the labelling or advertising that it contains GMO's [genetically modified components], consists of GMO's or is produced from GMO's according to Community legislation.

We understand that this paragraph indicates that it is possible to label a food as organic, whether processed or not, if 0.9% or less of the content of a given ingredient is genetically modified. This is due to the fact that the regulation on labelling genetically modified food (Regulation 1829/2003)[82] exempts from such labelling those products in which the accidental presence of GMO's is below the 0.9% threshold. In other words, European legislation accepts that conventional and organic products with a GMO presence below the mentioned threshold do not have to be labelled as "genetically modified". This is the same as saying that those products that contain a genetically modified element below 0.9% do not loose their "organic" label.

Article 12 of the Regulation (EC) No 1829/2003 of the European Parliament and of the Council of 22 September 2003 on genetically modified foods and feed. Scope of the application of the labelling provisions:

1.- This Section shall apply to foods which are to be delivered as such to the final consumer or mass caterers in the Community and which:
a) contain or consist of GMO's, or
b) are produced from or contain ingredients produced for GMO's.

2.- This Section shall not apply to foods containing material which contains, consists of, or is produced from GMO's in a proportion no higher than 0.9 per cent of the food ingredients considered individually, or food consisting of a single ingredient, provided that this presence is adventitious or technically unavoidable.

Nevertheless, even though the right to label as organic is upheld in these circumstances, a lot of consumers reject organic products that do not meet the "0 genetically modified" or "genetically modified free" demand, which has no legal ground.

Unlike what we have said above concerning the impossibility of confirming that a food item, or ingredient, is organic by analytical techniques, the presence of genetically modified components in any food is readily detectable, even though they may be present in extremely low quantities. The technique, known as the "polymerase chain reaction"[83], commonly referred to as "PCR", is the basic one used in official protocols to detect and quantify each one of the genetic modifications introduced by genetic engineering authorised in Europe and other countries[84]. Entities seeking authorisation to commercialise genetically modified crops and food, or to grow their seeds, must provide the methods required for their identification in processed food, or in seed mixtures. The European Commission's Joint Research Centre web site (http://mbg.jrc.ec.europa.eu/) provides those interested with all the information needed for their detection.

On the grounds of this ease of detection, a lot of consumers can demand, and many do so, that organic food and products be wholly free from genetically modified components, even though these may be authorised in Europe after having successfully passed the EFSA assessment and having been declared harmless both for the heath of consumers and for the environment. That is to say, in spite of their being harmless foods or ingredients.

The presence of genetically modified components in organic food can occur for two main reasons. Firstly, the wind carries pollen from some plants, such as corn, which in certain circumstances, can reach the external rows of an organic field that may be nearby. Secondly, the reality of harvesting and storing farm produce in general, and of cereals and legumes in particular, means that it is extremely difficult, if not practically impossible, to ensure complete 100% separation.

We have pointed out that Regulation 834/2007 accepts the presence of 5% of non-authorised products, as long as these are not genetically modified. In this sense, Whereas clause 25 states:

It is however considered appropriate to limit the use of the EU-logo to products which contain only, or almost only, organic ingredients in order not to mislead consumers as to the organic nature of the entire product. It should, therefore, not be allowed to use it in the labelling of in-conversion products or processed foodstuffs of which less than 95% of its ingredients of agricultural origin are organic.

The difficulty of completely separating organic cereals and legumes from non-organic ones that contain genetically modified elements is made patently obvious in the pure seed production standards. In this sense, the Order of the Spanish Ministry of Agriculture of 1 July 1986[85] states that 1% of other different lines is allowed in the production of pure line seeds, and 2% is acceptable in certified hybrid seed, whereas for openly fertilised seeds a tolerance of up to 5% of the non-standard plant is admitted. Therefore, it seems rather inconsistent to accept up to 5% of non-organic products in food, or of seeds from other lines, while limiting the accidental and involuntary presence of genetically modified components to 0.9%, even more so when the reasons given are not of a scientific nature, but merely subjective.

In the United States, the National Organic Program[86] of the Department of Agriculture prohibits the use of genetically modified crops, specifying that "to label a product as organic ... excluding methods used to genetically modify an organism, and methods that are not possible under natural conditions..."[87]. It explicitly refers to cell fusion and micro and macro-encapsulation, but does not mention induced mutations and other techniques that are explained below to introduce genetic modifications in crops.

Considering the comments that appear in the list of substances that the National Organic Program accepts, we deduce that genetically modified seeds are considered to be "synthetic". According to the International Federation of Organic Agricultural Movements (IFOAM), an organisation that brings together organic agriculture associations from around the world, genetically modified seeds are not accepted due to their lack of safety[88]. However, it offers no proof of this possible lack of safety, nor does it specify if it refers to possible problems for the consumer and/or for the environment. Due to this absence of proof for the stated lack of safety, we believe that rejecting the use of genetically modified seeds by organic agriculture is devoid of any scientific basis.

CHAPTER III: GENETICALLY MODIFIED FOOD

3.1.- Historical sketch

The genome of a genetically modified plant has been modified by genetic engineering techniques to insert one or several new genes, or to modify some of the plant's own genes. As a result of this modification, the plant has one, or several, new characteristics[89].

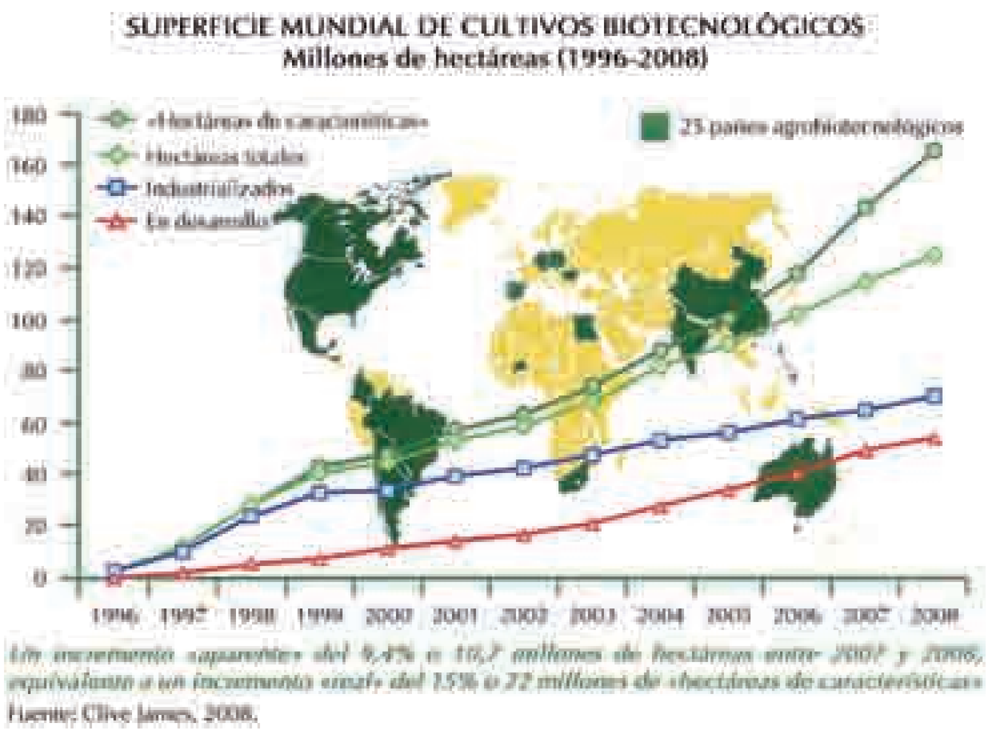
The molecular biology and genetic engineering techniques needed to isolate an organism's gene and insert it into another one were developed in the 1970's. We must remember that a gene is a segment of DNA that is capable of working in any organism if it has been properly prepared[90].

The first genetic transformations of plants were presented on the same day at the Miami Winter Symposium back in January 1983[91] by three different groups, the Belgian group led by Van Montagu and Schell[92] from the University of Ghent, the American group led by Chilton[93] from the University of Washington in Saint Louis (Missouri), and Horsch's group[94] from Monsanto. These three, independent groups of researchers had managed to make tobacco or petunia plants resistant to antibiotics by inserting the corresponding functional bacterial genes into their cells. The door to the accurate and specific modification of an organism's genes had been opened. Practically immediately, the scientific community and seed and agrochemicals producing companies recognised the importance that this new gene insertion technique could have on a plant to improve its characteristics.

Nevertheless, it would not be until 1996 when the first genetically modified crops were commercialised. Some 1.7 million ha[95] were sown in that year in 6 countries, mainly in the USA and Canada. The first crops were: glyphosate herbicide tolerant soya and corn-borer resistant corn. Since then, a considerable interest has developed in the growing of genetically modified varieties.

In 2008, over 125 million ha (8.3% of the worlds tilled farmland) was used to grow genetically modified crops in 25 countries[96] (Figure 5), 15 of which are developing countries. Figure 6 shows the countries that planted genetically modified crops in 2008, as well as the surface area employed and the main crops grown. Of the 13.3 million farmers that decided to grow them on their farms, 12.3 million were small farmers in developing countries. The main genetically modified crops were varieties of glyphosate and glufosinate ammonium herbicide tolerant soybean, maize, canola and cotton. These crops were planted on a surface area of 79 million ha (63% of the total world surface area sown with genetically modified crops).

Figure 5.- Global Area of Biotech Crops (1996 – 2008)



Taken from C. James (2009), "Global Status of Commercialised Biotech/GM Crops 2008". Brief 29 (http://www.isaaa.org).

Figure 6.- Biotech Crop Countries and Mega-Countries 2008.

Taken from C. James (2009).

From the outset, the private sector has played an important role (excessive, in the opinion of many people) in the development of genetically modified plants, with less, albeit extremely important, involvement by the public sector. At present, the main multinational companies in this field (though not necessarily in order of importance) are, among others: Monsanto, Syngenta, BASF, Bayer, Dow-Chemical, Pioneer Hi-Bred, Dupont.

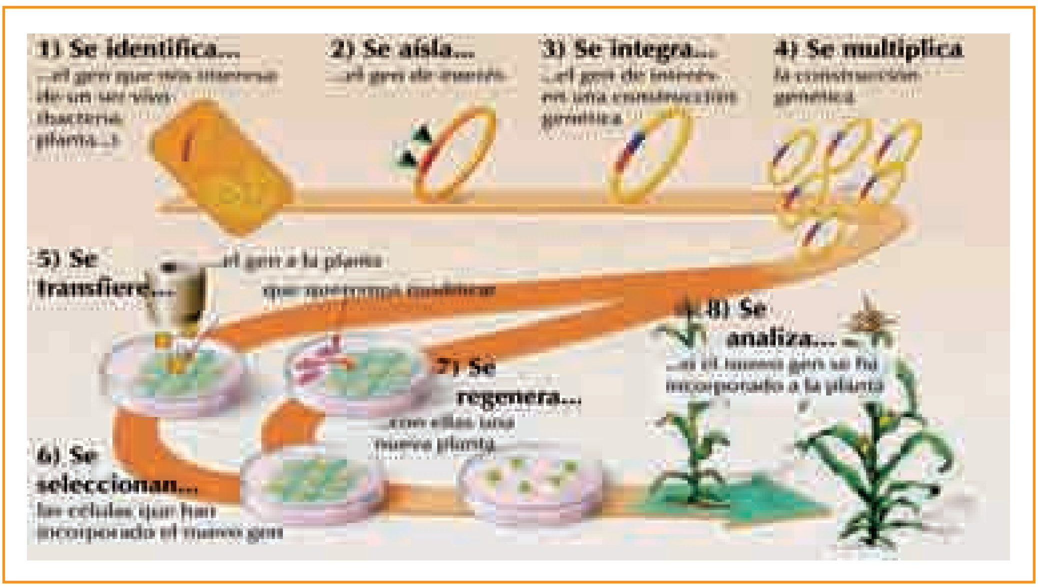
3.2.- How to make a genetically modified plant

The process to obtain a genetically modified plant rests on 3 scientific pillars:

- Modification of DNA: cutting the segment that carries the gene of interest and joining it to another piece of a different DNA, thus preparing it to be inserted into a cell.
- The insertion of the already prepared DNA segment into the receiving plant cell.
- The in vitro techniques to culture plant tissue permit to regenerate the entire plant from the cell that has received the gene of interest.

This process, with its three steps, is summarised in Figure 7.

Figure 7.- How to make a genetically modified plant



Taken from: PC David. Molecular Biology. Elsevier, 2005

First of all, the gene that will provide the characteristic of interest is identified (Stage 1). This gene can be taken from any type of organism. For example, the gene that confers resistance to certain insect species comes from the soil bacterium *Bacillus thuringiensis,* which was mentioned above when describing pest control methods in organic farming. In Stages 2 and 3, the gene is isolated by cutting the suitable DNA strand, joined to another DNA strand (Stage 3) and prepared to function in the cell that will receive it. Thousands of copies of the prepared gene are needed for each gene insertion experiment into plant cells, because in each experiment several hundreds or thousands of cells are transformed. Therefore, we need to obtain hundreds or thousands of copies of the gene we have prepared. This "photocopying" operation of the prepared gene is carried out on microorganisms and it is called "cloning" (Stage 4).

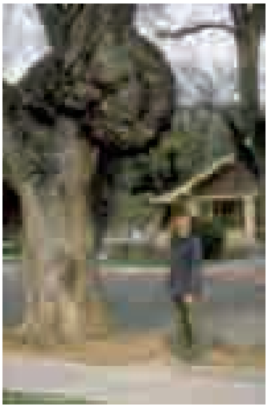
The insertion of the prepared gene into the plant cells (Stage 5) can be achieved by two different procedures, depending on the plant to be transformed:

- The so-called 'gene gun', an apparatus that works in a very similar manner to a compressed air gun, forces the entry of the new gene into the plant cells;
- The soil bacterium Agrobacterium tumefaciens is capable of naturally inserting its own genetic material into numerous plant species entering through wounds in the plant tissue, thus causing a tumour called the "crown gall". Figure 8 shows a tree with this tumour.

This bacterium is prepared so as to insert the desired gene into the plant cell without provoking the disease.

Either one of these two procedures are routinely used to insert a DNA segment into a plant cells.

Figure 8.- Crown gall caused by the soil bacterium *Agrobacterium tumefaciens*



The following stage (6) consists of the identification of those cells that have incorporated the new gene, and their selection. Entire plants can be regenerated from these cells by *in vitro* tissue culture methods (Stage 7). In this way, all of the regenerated plant cells will have the new gene and thus possess the specific characteristic conferred by the gene in question.

Finally, the plants and their edible parts, will be subject to the relevant analyses to determine their agronomic characteristics, as well as their safety for consumers and the environment.

Throughout this process the best plant from all points of view shall be selected. From it the new gene will then be transferred to commercial varieties by classic cross-breeding techniques. Thus, many commercial varieties of a single crop can be obtained from a single genetically modified plant, each one with its different agronomic characteristics, but all of them will carry the new property. Table 3 shows 88 varieties of genetically modified maize produced by different seed companies with the same insect-resistance characteristic. As can be seen, even though the original genetically modified plant is owned by the multinational, Monsanto (St. Louis, Mo., USA), numerous companies have derived commercial varieties from it.

Table 3.- 88 varieties of genetically modified maize produced by different seed companies from the same genetically modified plant called MON-00810-6. This set of letters and numbers specifically identifies a particular genetic modification and receives the name of "event" (see Table 4 for its definition). The date given in brackets beside each variety corresponds to the date of its authorisation. The varieties that appear in green are included in the European Catalogue of Plant Varieties.

88 variedades de maíz MG derivadas de MON-ØØ81Ø-6 están autorizadas para su comercialización en España (mayo 2008)

Empresa comercializadora	Variedad (fecha de autorización en BOE o en el Catálogo Europeo*)
Pioneer Hi-Bred	PR33P67 (11/03/03), PR32P75 (16/02/04), BACILA (11/08/05), PR32R43 (11/08/05), PR32W04 (11/08/05), PR34N44 (11/08/05), PR36R11 (11/08/06), PR31N28 (07/09/06), PR33B51 (07/09/06), PR36B08 (07/09/06), PR31D21 (25/04/08), PR31O61 (25/04/08), PR31P42 (25/04/08), PR32T86 (25/04/08), PR35Y65 (25/04/08), ELGINA [illegible], OLIMPICA [illegible], BOLSA [illegible], [illegible]
Monsanto Agricultura	DKC 6575 (11/03/03), DKC 6550 (16/02/04), DKC4442YG (11/08/05), DKC5784YG (11/08/05), DKC6041YG (11/08/05), DKC 5018YG (07/09/06), DKC6631YG (05/10/06), DKC6418YG (11/05/07), DKC6451YG (11/05/07), DKC5667YG (11/05/07), DKC6844YG (11/05/07), TABALA YG (25/04/08), [illegible]
Limagrain Ibérica	ALIACAN BT (11/03/03), ARISTIS BT (11/03/03), GAMBIER BT (16/02/04), CAMPERO BT (16/02/04), HELEN BT (11/08/05), BELES SUR (07/09/06), LUSON BT (07/09/06), VIRIATO BT (07/09/06), ASTURIAL BT (07/09/06), ABREGO BT (07/12/06), FONCHO YG (11/05/07), THURRO YG (11/05/07), LG0711 YG (25/04/08), NOVELIS [illegible], [illegible]
Semillas Fitó	JARAL BT (16/02/04), SF1025T (11/08/05), SF1036T (11/08/06), SF1112T (11/08/05), SF4701T (07/09/06), AZEMA YG (07/09/06), CARELLA YG (25/04/08)
Arlesa (Euralis)	CUARTAL BT (16/02/04), RIGLOS BT (11/08/05), ES MAYORAL YG (25/04/08), ES ARCHIPEL YG (25/04/08), ES CAJOU YG (25/04/08), ES PAOLIS YG (25/04/08), ES ZOOIAC YG (25/04/08)
Koipesol	PROTECT (16/02/04), KAPER YG (25/03/07)
Agrar Semillas	FOGGIA (11/08/05), MAS 60YG (11/05/07), MAS 59YG (25/04/08), MAS 71YG (25/04/08)
Corn States Intl.	EVOLIA YG (07/09/06), BENJI YG (07/12/06), KOFFI YG (07/12/06), ROCCO YG (07/12/06), PLACIDO YG (25/03/07), TONIC YG (11/05/07)
KWS	KXA5491 YG (11/05/07), [illegible]
Caussade Semences	VENICI YG (25/03/07)
RAGT	RUGBYXX YG (25/04/08)

Source: Antama Foundation (http://www.antama.org)

Genetic engineering techniques are used to improve crops in cases where the desirable characteristic is present in a sexually incompatible organism, or in those cases where the genes that confer it are not active in the edible part of the plant. As an added advantage, this technology considerably shortens the development time of the new improved variety with respect to conventional methods[97]. This is due to the fact that genetic engineering techniques introduce very few modifications to the genome, as we will see below, and it is not necessary to eliminate undesired characteristics which, quite often, are transferred from a wild variety or a mutated variety to the variety that one wishes to develop.

3.3.- Types of genetically modified crops

The improved characteristics of genetically modified crops, both commercialised and at different stages of development, can be classified into two groups:

1. Improvement in agronomic characteristics:
   a. Resistance to insects; tolerance of weed killers.
   b. Resistance to virus and diseases.
   c. Tolerance of water scarcity.
   d. Tolerance of marginal conditions such as saline or acidic soils.

2. Improvement in nutritional characteristics: increase in the content of vitamins, essential amino acids, healthy fatty acids, minerals, etc.

3.3.1.- Improvement in agronomic characteristics

The most extensively developed crops are those that improve some agronomic characteristics to reduce losses as a result of the attack of certain species of insects and viral diseases, and to improve agronomic practices by using less aggressive weed killers (herbicide crops)[98]. At present, the European Union has only authorised insect resistant and/or herbicide tolerant crops for use as food, or food ingredients, as can be seen in Table 4. In Europe, the only genetically modified crop authorised for cultivation is an insect resistant maize called MON 810.

Table 4.- Genetically modified crops that are authorised in Europe (adapted from R. Batista and MM Oliveira. 2009. "Facts and fiction of genetically engineered food". Trends in Biotechnology 27(5), 277-286).

Crop	Producer	Characteristic	Authorisation date
Soybean			
GTS 40-3-2*	Monsanto	tolerates herbicides	1996
A2704-12	Bayer Crop Science	tolerates herbicides	2008
Maize			
T25	Bayer Crop Science	tolerates herbicides	1998
MON 810	Monsanto	insect resistant	1998
MON 809	Pioneer Hi-Bred	insect resistant	1998
Bt11	Syngenta	insect resistant tolerates herbicides	1998 2004
MON 863 x NK603	Monsanto	insect-resistance; tolerates herbicides	2003
NK603	Monsanto	tolerates herbicides	2005
GA 21	Syngenta	tolerates herbicides	2008
MON863	Monsanto	insect resistant	2003 and 2006
DAS1507	Pioneer & Dow Agro Sciences	insect resistance; tolerates herbicides;	2006
DAS1507 x NK603	Pioneer & Dow Agro Sciences	insect resistance; tolerates herbicides;	2007
NK603 x MON810	Monsanto	insect resistance; tolerates herbicides;	2007
DAS59122	Pioneer & Dow Agro Sciences	insect resistance; tolerates herbicides;	2007
Canola			
GT73	Monsanto	tolerates herbicides	1997
T45	Bayer Crop Science	tolerates herbicides	1998
MS8 x RF3	Bayer Crop Science	male sterility	2007
Cotton			
MON1445	Monsanto	tolerates herbicides	2002
MON531	Monsanto	insect resistant	2002
MON15985	Monsanto	insect resistant	2003
MON15985 x MON1445	Monsanto	insect resistant; tolerates herbicides	2003
MON531 x MON1445	Monsanto	insect resistant; tolerates herbicides	1997
Sugar beet			
H7-1	KWS SAAT / Monsanto	tolerates herbicides	2007

*This combination of letters and numbers unmistakably identifies each crop and is called the "event". An event is defined by the specific gene that has been inserted into the plant and by the place in the genome where it has been inserted. Numerous commercial varieties can be obtained from a single event (by crossing). All plants will have the same gene inserted in the same place in the genome.

3.3.1.1.- Insect resistant crops

Commonly known as "Bt crops", they carry a bacterial gene from a soil bacterium called *Bacillus thuringiensis* (which, incidentally, is where they get their name from) that enables the plant to synthesize a protein that is toxic for certain types of pest insects. Some of these insects protect themselves since the first larval stadium by "boring" (which is where they get their name) the cornstalk, or the cotton capsule, where chemical pesticides sprayed onto the plants do not affect them. Figure 9 shows cornstalks and cobs damaged by corn borers.

There are different sub-species of this soil bacterium. Each one produces an insecticide toxin that is slightly different from the others, so that each one affects a few species of pest insects, as is indicated in the following table[99]:

Subspecies of Bacillus thrugingiensis	**Main target insect**
kurstaki	Lesser cornstalk borer, cabbage borer, cotton borer
tenebrionis	Colorado potato beetle
kumamotoensis	Western corn rootworm (larvae)

Figure 9.- Cornstalks and cobs damaged by the corn borer.

- left: the first one is an intact cornstalk. The next sample has a hole made by a borer to get inside (arrow). The three on the right have been attacked by the borer.
- right: corn cobs attacked by the borer, showing different levels of infestation.

- left: corn borer larvae feeding off the inside of the stalk.
- right: cornstalks damaged by the borer, broken and difficult to harvest.

Cotton and corn are the most widespread Bt crops. Rice and eggplant will be commercialised very soon in China and in India, respectively.

We ought to point out that the bacterium B. *thuringiensis is widely* used in fumigation formulations, both in organic farming (as we have already seen above), as well as in conventional farming. The toxicology of this bacterium and its toxin have been subject to extensive study. It has proved to be non-toxic to humans or vertebrates[100].

3.3.1.2.- Herbicide tolerant crops

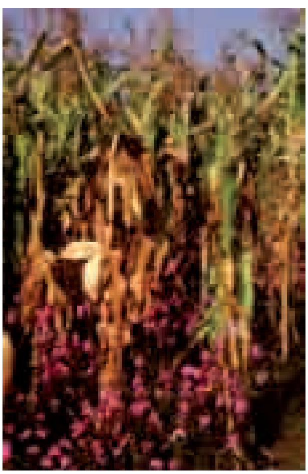
Weed killers, or herbicides, interfere with some of the metabolic pathways[101] important for the development and growth of the target plant, so that the products of that metabolic pathway are not synthesized. As a result, the plant fails to develop normally and dies. In order to carry out this action, the weed killer has to interact with one of the enzymes of this pathway, inactivating it. It is as if a stopper were placed somewhere in the metabolic pathway, interrupting its flow.

Different strategies can be used to make the plant tolerate a weed killer[102]. For example, a gene from another species that codes for a somewhat different target enzyme can be inserted, so that the herbicide will not inactivate it. The plant would now have 2 enzymes to catalyse the same reaction, its own one would be inactivated by the weed killer, but the other one would not and could, therefore, bring about the corresponding reaction. Thus the plant would develop normally. Non-genetically modified, *Clearfield* maize carries a mutation that works like this in practice: the weed killer does not affect the plant's enzyme. Another possibility is to provide the plant with another species' gene that is capable of destroying the weed killer whenever this is to be found inside the plant cell, thus the plant would be able to grow.

Most genetically modified herbicide tolerant plants tolerate glyphosate, manufactured by the multinational Monsanto though the original patent for this product expired in 2000. This herbicide is very effective against many types of broad-leaved weeds and affects a metabolic pathway that is not present in humans, or in many animals: the pathway that synthesizes aromatic amino acids (essential to humans)[103]. Moreover, it is a compound that easily degrades in nature, thus it is much less aggressive to the environment than are other frequently used weed killers. A recent study has shown that the concentration of glyphosate in surface runoff water is 7 times less than that of other herbicides frequently used in conventional soybean cultivation[104].

Herbicide tolerant sorghum has proved to be an effective method to control the weed known as "witchweed" *(Striga spp)*[105], an important pest in Sub-Saharan Africa because it parasitically feeds off crop roots. Thus, even though it is eliminated manually (women tend to be the usual "herbicide" for small and subsistence farmers in developing countries), the plant is damaged (Figure 10). Sorghum seeds treated with a suitable herbicide protect the plant from witchweed.

Figure 10.- Witchweed plant (with pink flowers; *Striga spp*.) in a cornfield (left), and diagram showing how it feeds off the roots of a corn plant (right). It also parasitises sorghum, groundnuts (peanuts) and other crops.



Taken from Chrispeels and Sadava (2003). Op. cit.

3.3.1.3.- Virus and disease-resistant crops

Several virus resistant crops are authorised in the USA, as well as in other countries, such as papaya and various types of squash and melons. Viruses are very difficult to control given there are no effective products available to combat them. They spread with great ease throughout the crop and cause big losses, some times up to 80% of the crop, or more. As a result, the papaya was practically wiped out in the 1980's in Hawaii due to the virus called ringspot. In the early 1990's, scientists at Cornell University in the USA developed a virus resistant papaya[106] which was authorised for cultivation in 1998. At present, the papaya crop has recovered, and over 40% of the papaya grown in Hawaii is virus resistant.

3.3.1.4.- Abiotic stress resistant crops

According to the study carried out by the International Food Policy Research Institute climatic change will negatively affect global agriculture and human health[107]. Even though this will prove beneficial in some regions around the world, worldwide production will fall considerably, resulting in higher food prices. As a result, a general decrease in food security is expected, as well as a drop in the total amount of calories consumed by the people currently in highest need of food. The report insists on the need to increase agricultural research and to make use of all scientific advances. Likewise, it highlights the need to improve rural infrastructures so that small and medium-sized farmers can benefit from the improved crops.

We must also mention drought tolerant and crops able to grow in marginal lands. Their commercialisation has not yet been authorised, but field tests are at a very advanced stage and authorisation is expected soon. As is well known, the percentage of land affected by drought has doubled between 1970 and 2001, increasing from 10-15% to 30% over this period[108]. Agriculture uses about 70% of available drinking water[109]. On average, from 2,000 to 5,000 l of water, depending on the food in question, are needed to produce 1 person's daily food intake. Table 5 shows the amount of water needed to produce some common food items.

Drought tolerant crops enable us to obtain the same amount of food with up to 30% less water, which implies an increase in crop yield from 6% to 10% in these conditions. At present field tests with rice, maize, wheat and the groundnut are well advanced. It is expected that drought-resistant maize and wheat will be commercialised in a couple of years (See Table 6). Drought tolerant crops are the subject of intense research in developing countries, particularly in India and Sub-Saharan African countries. This research is supported by public-private consortia between multinational companies like Monsanto and Syngenta, as well as private foundations, such as the Bill & Melinda Gates Foundation[110].

Table 5.- Average consumption of water used to produce some foods. Adapted from the FAO web page: ftp://ftp.fao.org/agl/aglw/docs/factsheet_wwf_spa.pdf

PRODUCT	LITRES OF WATER PER KG. PRODUCT
wheat	1.200
rice	1.700
maize	450
patato	160
soybean	2.300
beef	15.000
pork	6.000
poultry	2.800
egss	4.700
milk	900
cheese	5.300

Table 6 – Some drought resistant genetically modified crops

Crop	**yield***	**notes**	**reference**
wheat	20%	Field tests in Australia	http://www.agrodigital.com/PlArtStd.asp?CodArt=58658
maize	6 – 10%	Field tests in the USA	http://www.fundacion-antama.org/noticia/la-biotecnologia-posee-semillas-de-esperanza-para-africa

*compared to the traditional crop in drought conditions.

Acidic soil covers approximately 30% of ice-free land, which represents 40% of farmed land. In South America alone there are over 850 million hectares of acidic lands. Acidic lands also spread across Sub-Saharan Africa, Europe, south-east Asia and half the east of the USA and Canada. Most small and subsistence farmers in developing countries farm this type of marginal soil. Conditions in acidic soil solubilise aluminum which inhibits root growth. In alkaline soils the lack of soluble phosphorous stops the plant from completing its life cycle, thus it fails to produce seeds. Crop yields in these types of soil are very low. Researchers at the International Corn and Wheat Improvement Centre (CIMMYT, Mexico) have developed genetically modified crops with the same genetic modification that overcome both of these problems, namely acidic and alkaline soils, allowing the same crop to be grown on both types of land[111].

None of these crops need extra agrochemical products to grow. The increase in yield is simply due to the reduction of losses and/or to making the most of not very productive land, without the need to extend cropland areas.

3.3.2.- Improvement in nutritional characteristics

All main basic crops (rice, maize, wheat) lack some nutrients, thus a varied diet of fresh products is essential to good health. Nevertheless, over 50% of the world population, mainly in developing countries, does not have access to a variety of nutritional and healthy food for several different reasons[112]. Therefore, even though their diet could provide a suitable amount of calories, it is estimated that around half the world's population suffers from "micronutrient malnutrition", or "hidden hunger", expression which refers to the deficit suffered by this group in terms of essential nutrients such as vitamins, minerals (mainly iron), and some amino acids (low quality protein)[113]. For example, it is estimated that over 3,000 million people in developing countries suffer from iron deficiency, and some 3 million preschool children have visible eye damage due to vitamin A deficiency[114]. Certainly, these deficiencies can be made good by a varied diet of fruit, vegetables, fish and meat, and cereals. However, the majority of people in developing countries whose diet consists of one or two basic foodstuffs (e.g. maize, rice or wheat) cannot afford the other food items.

This second group of genetically modified crops that provides nutritional advantages to the consumer may not inspire a lot of interest in developed countries, like Europe, the USA, Japan or Australia, because the majority of people living in those countries can afford a wide selection of foodstuffs. Nevertheless, they can have a great impact on the heath of people in developing countries. In this group we find crops with higher content of certain vitamins (vitamin C, vitamin A and vitamin E) and minerals (mainly iron and zinc), essential amino acids, healthy fatty acids, antioxidants and the starch composition best suited to diabetics.

In this group there is a wide selection of crops at different stages of development and commercialisation. There are still very few crops with nutritional improvements that have been authorised around the world. Maize with high lysine content (an essential amino acid for humans and farm animals) was authorised in 2006 in the USA and Canada[115]. Some months ago Canada and Mexico authorised a soybean with high oleic acid content. The USA is expected to follow suit soon[116]. The oil in this soybean contains 80% oleic acid, a similar percentage to that found in olive oil[117], but substantially less expensive. As yet, none of these crops have been authorised in Europe.

Even though some of these nutritional improvements could also be introduced by non-transgenic techniques, such as mutagenesis (described below), an important problem is the time it takes to identify the characteristics of interest in the plants thus modified and to pass these characteristics on to elite commercial varieties. Quite often, genetically modified techniques cut down substantially on this time factor[118].

Perhaps the best known crop with improved nutritional characteristics is the so-called *Golden Rice,* which gets its name from its yellow-orangey colour due to the accumulation of β-carotene, a precursor to vitamin A. This genetically modified crop was developed by researchers I. Potrykus and P. Beyer to relieve health problems caused by a serious deficiency in vitamin A in large sections of the world's population for whom rice is a staple food, primarily in south-eastern Asian countries. According to the World Health Organisation, vitamin A deficiency causes somewhere between 250,000 to 500,000 children to go blind every year. Moreover, this deficiency weakens the immune system of around 40% of children under 5 years-of-age in developing countries and significantly increases the risk that common children's diseases may become serious illnesses[119].

Rice does not accumulate β-carotene naturally in the edible seed endosperm, and there is no cultivated or wild rice variety or species that does so. Consequently, the only possibility of obtaining it was to employ genetic engineering techniques to insert the necessary genes from other plants. This development was fully financed by public funds, though some elements patented by several multinationals and public research centres had to be used. In any case, patent owners gave up their rights for the humanitarian development of this crop, so that it could be available in developing countries without any surcharge.

Of all the criticisms that have been made about Golden Rice, the only one with any scientific basis was that the initial crop did not accumulate enough β-carotene. Therefore, excessive amounts of rice had to be eaten in order to reach the recommended daily intake of vitamin A. Since 2005, an improved variety has been made available[120] that contains a high amount of β-carotene which is efficiently converted into vitamin A in the organism[121]. An intake of about 100 g (raw) rice provides between 80% and 100% of the necessary daily amount of vitamin A. Studies to date have confirmed that this crop is safe both for consumers as well as for the environment. Nevertheless, it has not been commercialised yet due to the controversy[122], completely unfounded in our opinion, that continues to surround this clearly humanitarian crop. It is expected that it will be definitively commercialised within a couple of years.

Work is being actively done so that other basic food crops for developing countries, such as cassava, yam or sweet potato, and sorghum, can also accumulate β-carotene. In 2009, researchers at the Universidad de Lleida in Spain obtained a corn with very high concentrations of β-carotene (169 times more than current varieties), vitamin C (6 times more) and folic acid (twice more)[123]. This maize gives a moderate yield and is not a hybrid, thus farmers can store its seed from one year to the next.

As is well known, plant protein, unlike animal protein, does not provide us with all the amino acids we need, or in a proportion suited to our vital requirements. It is not a "complete protein", so dietitians advise to complement legumes with cereals, for example lentils with rice, to compensate for the deficiencies of each one. A variety of maize with a 40-fold higher concentration of lysine[124] has recently been commercialised in the USA. The concentration of lysine in current varieties of maize is very low.

The concentration of antioxidants in certain foods has been significantly increased by genetic engineering techniques. For example, in 2008, the development of a purple-coloured tomato (due to its high concentration of anthocyanines)[125] was published.

In addition to the already mentioned soybean with a high oleic acid content, the composition of the fatty acids of oil plants has also been modified to obtain vegetable oils and margarines with healthier fatty acids[126]. For example, a soybean that produces stearidonic acid has been developed. Animal tissues can convert this fatty acid into eicosapentaenoic acid (an ω3 fatty acid from fish). Other examples are high oleic or high stearic acid canolas (to produce margarines *with a low trans* fatty acid content).

Table 7.- Some genetically modified crops with nutritional improvements expected to be commercialised in the near future.

Crop	Characteristic
soybean	High oleic acid content
	High ω-3, polyunsaturated fatty acid content
canola	healthier fatty acid composition
rice	High β-carotene (pro-vitamin A) content
	High iron content
maize	High oleic acid content
	Greater lysine content (essential amino acid)
	Higher β-carotene, folic acid and vitamin C content
potato	Greater amylose content
tomato	Greater antioxidant content
yucca	High β-carotene and low glucosinolate content

3.4.- Safety of genetically modified crops

This issue is by far the most important one for consumers, which explains why it has taken up, and continues to take up, enormous resources in order to ensure that genetically modified foods are, at least, as safe as foods produced by conventional methods.

From the point of view of human health and the nutritional properties of genetically modified foods, two groups can be considered:

- Those with genes that improve their agronomic characteristics (known as "input traits"), or those that will protect the plant against different forms of abiotic stress such as drought, excess salts (saline soil), or acidity (acidic soil)
- Those that improve nutritional characteristics (usually referred to in the literature as "output traits"): these have a greater concentration of vitamins, protein, essential amino acids, minerals or other compounds that benefit health (such as antioxidants), or a healthier fatty acid composition.

As far as we know, in all countries genetically modified crops have to pass a rigorous safety assessment process to determine possible health risks. These assessments are based on a large amount of diverse scientific data. We will briefly describe the type of tests that a company requesting authorisation to commercialise a genetically modified crop in Europe must carry out. The European system is the one with which we are most familiar, in addition to the fact that it is probably the most demanding one in the world.

All genetically modified crops in the European Union must pass an assessment of possible risks for consumer (as well for the environmental, as we will see below) and receive a positively favourable report from the EFSA as a prerequisite before being authorised[127]. This assessment aims to determine whether or not the genetically modified crop is as safe as the conventional crop before it was genetically modified. To this end, scientific data need to be submitted to be reasonably certain that the crop in question will not be harmful to consumers, knowing that there is no absolute certainty that this will indeed be the case, and that zero risk does not exist. EFSA Guidance documents describe the different stages and tests that genetically modified crops must undergo in the European Union[128].

It is important to point out that European legislation provides for risk assessment without taking into consideration the possible benefits that genetically modified crops can bring about, something which we will deal with at a later stage in this paper. We agree with the European Group on Ethics in Science and New Agricultural Technologies[129] that the impact assessments on genetically modified crops must take into consideration, in addition to the risks, the benefits that their use will bring about for health and the environment, as well as the risks and benefits of their non-use, including those of maintaining current practices and technologies. This failure to include benefits means that the overall assessment is not impartial and precludes society from taking into account an important issue when it comes to choosing that which, in overall terms, is most beneficial.

The risk assessment process does not assess the procedure through which the food has been obtained, but rather the end product, which is actually what consumers are going to eat, comparing it at every step with the conventional food before it was genetically modified. Therefore, what we are dealing with is a comparative study of the nutritional properties of both foods. Even though the safety of conventional foods for consumers has never before been assessed, the principle of *familiarity* is applied to conventional foodstuffs that are used as controls, because they have been grown and consumed for a long time.

3.4.1.- Safety assessment methodology

A detailed description of the tests that must be carried out and their results exceeds the scope of this paper. Consequently, we refer those interested in this matter to the previously mentioned EFSA Guidance documents.

The assessment of the risks that a new genetically modified food may have for consumers can be divided into 4 main stages, during the course of which the new genetically modified crop is studied in parallel with its corresponding conventional crop from which it has been obtained ("isogenic variety", that is to say, it has the same genes, except for the modifications introduced in the genetically modified crop) (Figure 11):

1.- Comparative analytic study of the genetically modified variety and of the conventional crop, identifying any differences on three different levels:

- Genome level: identification and characterisation of the gene, or genes, that have been inserted, and the place where they have been inserted into the genetically modified plant.
- Concentration of new protein(s) expressed by this gene or genes, or other new proteins that may have appeared in the transgenic plant as a result of the genetic modification.
- Concentration of chemical compounds synthesized by the plant: different compounds, or different proportions of usual compounds that the genetically modified plant synthesizes as a result of the modification.

2.- Study of the safety of the differences that have been found:

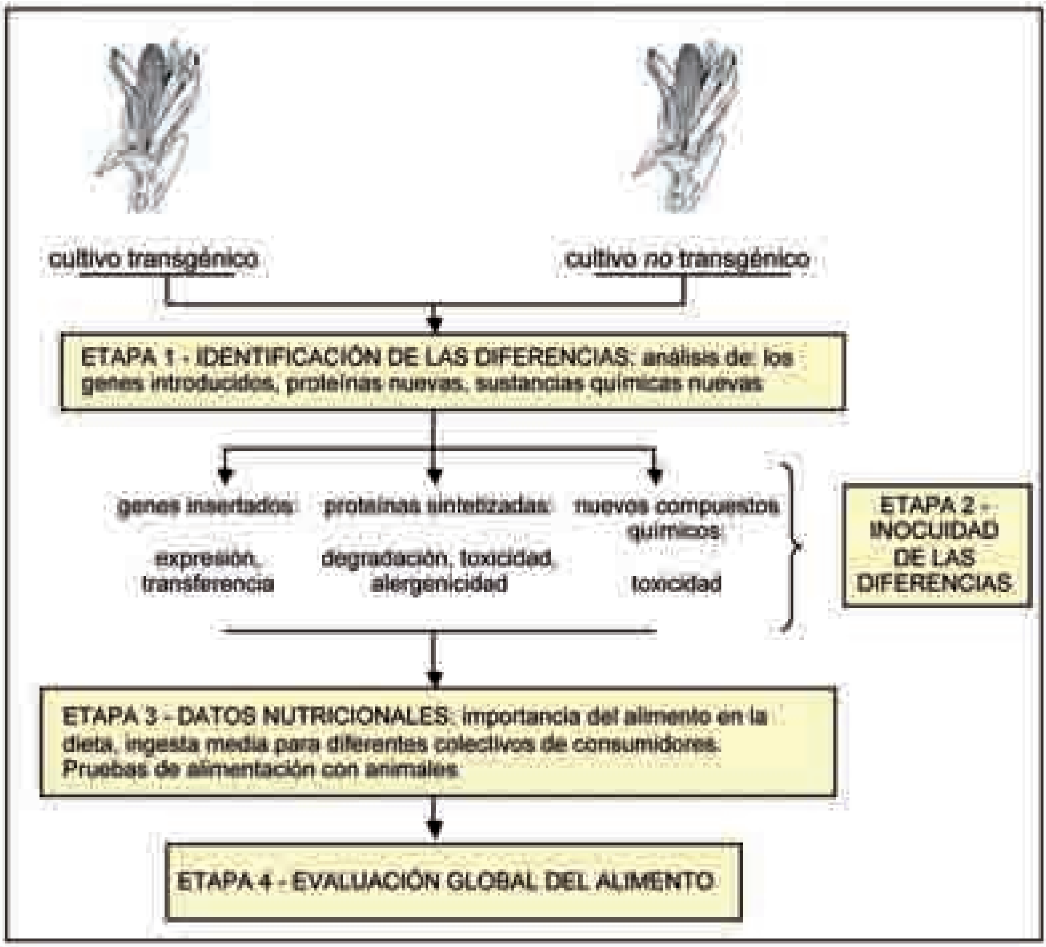
- Toxicity of the new protein(s) and/or of the new compounds that have been found.
- Allergenic feature(s) of the new protein(s).
- Digestibility of the new protein(s) and/or of the new compounds that have been found.
- Determination of the daily amount of this protein, or compound, that different consumer groups eat, or to which they can be exposed.

3.- Assessment of the nutritional data and animal feeding trials.

4.- Overall study of all the data obtained and assessment of the overall risk.

The genetically modified plant and the isogenic conventional one need to be grown at the same time in different places to carry out these studies, because the concentration of nutrients of a crop depends very much on the type of soil, the climate and the agronomic practices employed, etc. In this way the variability that the conventional crop may present is determined permitting to decide if the data obtained for the genetically modified crop fall or not within these variability ranges.

Figure 11.- Diagram of the stages to assess risk for consumers.



Adapted from the European Project, Entransfood (Contract No. QLK1-1999-01 182) and HA Kuiper, & GA Kleter. 2003. "The scientific basis for risk assessment and regulation of genetically modified foods". *Trends in Food Science and Technology* 14: 277-293.

The risk assessment for genetically modified crops is carried out for each genetically modified crop individually. This is what is known as a "case by case assessment". That is to say, for example, all insect resistant crops are not assessed jointly, because even though they carry the gene that codifies the B. *thuringiensis* toxin, these genes differ depending on the bacterial strain of origin, and/or the genetic modification that has been inserted in different places in the plant's genome. In technical jargon, the combination of the specific gene (prepared differently depending on the case) that has been inserted and the place where it has been inserted in the plant's genome is called the "event". Therefore, the event known as "MON810" (belonging to the multinational Monsanto) carries a certain gene that codifies the B. thuringiensis toxin that has been inserted in a specific and known place in the maize genome, while the event known as "Bt-176" (belonging to the multinational Syngenta) also carries the gene that codifies this toxin, though it is prepared somewhat differently and is inserted in another specific and known place in the maize genome.

A summary of the scientific details provided for the risk assessment of an event, as well as the overall EFSA assessment are given in a document entitled "Scientific Opinion". It is possible to consult these documents for each and every one of the assessed events in the web page of the EFSA Panel for Genetically Modified Organisms

(http://www.efsa.europa.eu/en/panels/gmo.htm).

Crops that improve agronomic characteristics authorised in different countries are *substantially equivalent* to the corresponding conventional crops from a nutritional standpoint. This means that they provide the same level of nutrients for the person as do conventional ones and, therefore, cannot be distinguished from them in this respect. It is quite obvious that crops that provide nutritional improvements can be substantially equivalent to the conventional ones in the concentrations of all other nutrients except for one(s) the concentration of which has been increased.

Prestigious entities such as the World Health Organisation[130], the American National Academy of Sciences[131], the FAO[132], the British Medical Association[133], the Union of German Academies in Science and Humanities[134], the United Kingdom's Royal Society[135], the American Toxicology Society[136], the American College of Nutrition[137], among others, have declared that genetically modified crops that have been approved for commercialisation do not present any more risks for human health than conventional ones, thus they can be considered as safe as the latter. In some cases it has been pointed out that some genetically modified foods may be safer than conventional ones, referring to the fumonisin problem, which we will analyse below.

During the last 13 years of constant increase in the cultivation of genetically modified crops, their potential impact on human and animal health has been subject to intense study without any evidence being found of any negative effects. Nevertheless, there are sectors in society that persist in speaking of the potential long-term risks, even though they do not specify what these risks might be. To study this question from a scientific perspective and to provide data to the European Commission, the German Federal Office of

Consumer Protection and Food Safety has published an extensive study (*BEETLE* Report) of over 100 scientific articles consulting, in addition, 52 health experts[138] in order to determine the possible long-term effects (10 to 20 years) of genetically modified crops on consumers and the environment. They conclude that, to date, no negative effects on human health as a result of the consumption of genetically modified food consumption have been found, in spite of the fact that there are over 50 genetically modified crops commercialised worldwide. Even though unexpected negative effects have come about in conventional crops, none have been found in genetically modified ones. Therefore, they consider it quite unlikely that any health problem may arise in the long term.

As regards Bt maize, this study highlights the fact that it is more likely to benefit health in the long term due to its lower fumonisin content, as is explained below.

3.4.2.- Antibiotic resistance marker genes

A question that is frequently mentioned is the possibility that the genes that confer resistance to certain antibiotics, present in some genetically modified crops, may pass through to the gut microbiota and thus contribute to increase the resistance of pathogenic microorganisms to antibiotics. Studies carried out to date have concluded that the likelihood of a gene present in a genetically modified plant being completely transferred (functionally speaking) to a gut microorganism is practically nonexistent due to the digestion process in the intestine. We must point out that current molecular biology and genetic engineering techniques enable the elimination of these genes from the commercialised plant. Taking this fact into consideration, the European Directive 2001/18 that regulates the commercialisation and release of genetically modified organisms into the environment bans the use of these genes in all crops, even in field tests as of 2008. Whatever the case, EFSA has issued an opinion as to the safe use of specific antibiotic resistance genes that are not used in human or veterinary medicine[139]. Thus, antibiotic resistant genes do not represent any risk for either people or the environment.

Therefore, we may conclude that the crops and foods approved for consumption do not represent any greater risk to consumer health than do conventional crops and foods, and that after 13 of increasing cultivation, it does not seem likely that they may have negative effects for consumer health in the long term.

3.5.- Contributions of genetically modified crops

We have mentioned above that the authorisation process for commercialisation of genetically modified foods, or cultivation of genetically modified seeds, only takes into account the risks, without considering the benefits that these crops afford us. In this section we provide a brief description of some of the positive features of genetically modified crops.

The positive contributions made by genetically modified crops can be grouped as follows:

1. Benefits for the health of farmers and consumers.
2. Agronomic benefits: reduction in the amount of insecticides used, reduction in the emissions of greenhouse gases, replacement of herbicides aggressive for the environment by less persistent ones, possible reduction of water consumption.
3. Socio-economic benefits.

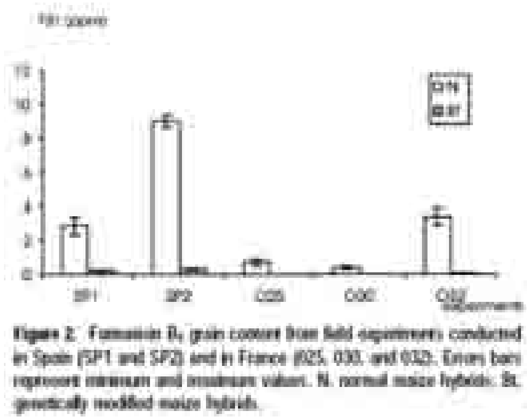
3.5.1.- Benefits for consumer health

The attack of herbivorous insects causes injuries to the plant that facilitate secondary infections by microscopic fungi which, in turn, can produce toxic compounds. The main problems in this sense have been detected, above all, in mainly organic corn and corn flours, in which mycotoxin levels, fumonisins to be exact, have been identified in higher-than-acceptable concentrations. These compounds, produced by some species of the fungus *Fusarium* and by *Aspergillus ochraceus,* cause diseases in livestock that quite often prove to be lethal. A link has been found in humans between fumonisin intake and cancer of the oesophagus. It has been further shown that fumonisins interfere with the assimilation of folic acid[140], an important vitamin during foetus development which prevents very serious congenital defects, such as anencephaly and spina bifida. In some areas of the south of the United States where mainly the Hispanic population has a large intake of maize in comparison to the non-Hispanic population, a high percentage of these congenital defects were found among the Mexican-American population. At that time, the concentration of fumonisins in corn was some three times above the current level.

Figure 12 shows fumonisin levels in conventional corn grown with the use of insecticides, and in insect resistant genetically modified corn that produces its own insecticide protein. Similar results were published by other researchers[141]. The drop in the fumonisin concentration in Bt maize can be up to 30-fold less than in conventional maize[142], though this varies depending on the level of the pest insect infestation and the variety of Bt corn that is sown, because not all Bt corns produce the same amount of Bt protein. This type of genetically modified maize is protected against the attack of insects that bore the stalk and live inside it, as well as the cob (Figure 9). As a result, protected plants do not suffer from the infestation of *Fusarium* genus fungi.

Maximum fumonisin levels in Europe are regulated by European legislation[143] depending on the type of foodstuff in question: unprocessed maize, maize-based foods, flours, breakfast cereals, foods for breast-fed babies and infants, etc. The food safety Rapid Alert Food and Feed System of the European Union[144] has withdrawn over 600 batches of organic (31% of the cases) and conventional (69%) products from the market between 2003 and 2008 as a result of having higher fumonisin concentrations than the maximum acceptable levels[145]. The twenty-seven member states of the European Commission and EFSA participate in this system.

Figure 12.- B1 fumonisin levels in conventional and genetically modified maize grown in field tests in Spain (SP1 and SP2) and France (O25, O30 and O32). The error bars represent maximum and minimum values. N: normal maize hybrids; BT: genetically modified hybrids.



Taken from B. Bakan, D. Melcion, D. Richard-Molard, & B. Cahagnier. 2002. Op. cit.

In Spain, the Assessment Group for New Varieties of Extensive Crops (Grupo para la Evaluación de Nuevas Variedades de Cultivos Extensivos) found that in the 2004 to 2006 campaigns 40% of conventional varieties contained fumonisin levels over those authorised by European legislation. In the 2007 campaign, the percentage of crops that did not comply with the standard fell by 32% because the authorised fumonisin level doubled with respect to previous years on entering into force the already mentioned Regulation 1126/2007.

Losses due to high fumonisin concentrations in maize (withdrawn from the market for human and animal health reasons) amounted to tens of millions of dollars every year in the USA[146], and could even be much greater in other parts of the world.

The health benefits for people and animals of Bt maize, and presumably of other crops with the same genetic modification, can be particularly important in developing countries where maize is the main food staple.

3.5.2.- Benefits for farmers' health

Frequently in developing countries farmers spray their crops with a hand-held apparatus as shown in Figure 13. This method leads to a high number of intoxications every year that give rise, in turn, to a high death rate.

Figure 13.- Manual method for spraying a crop with insecticides, frequently used by small farmers in developing countries.

Workers on farms in developing countries, where health standards are usually deficient, are those who suffer most intoxications due to insecticides. Only 25% of the worldwide production of insecticides is used in developing countries. However, of all worldwide deaths due to insecticide poisoning, 99% occur in these countries[147]. Because both Bt and herbicide tolerant crops greatly reduce the amount of chemical products needed to obtain good harvests (See Table 8), an important drop in farmer intoxications has been recorded. For example, in China Bt cotton farmer intoxications fell by 70% over 2002-2003, and an 8% drop was recorded in those working with Bt rice crops[148].

3.5.3.- Reduction in pesticide use

Table 8 provides examples of the reduction in the amount of pesticides in genetically modified crops. The big difference in the reduction that can be seen between Bt and herbicide tolerant crops draws our attention. Herbicide tolerant crops allow the farmer to modify his agronomic practices considerably reducing the number of herbicide applications per season, as explained below. By contrast, contact insecticides (applied by spraying) are not very effective in controlling insects that protect themselves inside the plant.

If the infestation is not very large, the farmer prefers to assume the losses without the added cost of a product that will afford his crop a low level of protection.

Genetically modified herbicide tolerant plants facilitate the use of low tillage agronomic techniques (Figure 14). It is not necessary to till the soil before planting. Indeed, planting can be done on the previous crop residue. When the seeds germinate and the plants begin to grow the herbicide is applied to eliminate unwanted weeds without affecting the crop. This substantially reduces top soil erosion, thus increasing the organic matter, nutrients and beneficial microorganisms[149].

Table 8.- Reduction of agrochemical products used in genetically modified crops

Crop	Country and year	Reduction	Reference
Bt Maize	USA - 2003 USA - 2006	1.9 million kg 3.4 million kg of active matter*	NCFAP 2008 Report**
Bt Rice	China - 2002/2003	80% insecticides	Huang and coworkers Science 308, 688, 2005.
Bt Cotton	India - 2001 USA - 2001 USA - 2003 China - 2002-2003	70% insecticides 1.5 million kg of active matter 1.6 million kg of active matter 43% insecticides	Qaim and Zilbermann, Science 299, 900, 2003. Gianessi & Carpenter, http://www.ncfap.org http://www.ncfap.org/whatwedo/biotech-us.php. Hossain and cols. Int. J. Occup. Environ. Health 10, 296, 2004.
Herbicide tolerant maize	USA - 2006	31.1 million kg of active matter	NCFAP de 2008 Report**
Herbicide tolerant soybean	USA - 2006	11.55 million kg of active matter	NCFAP de 2008 Report**
Herbicide tolerant cotton	USA - 2006	12.2 million kg of active matter	NCFAP de 2008 Report**
All genetically modified crops	USA - 2006	55 million kg of active matter	NCFAP de 2008 Report**
All genetically modified crops	Worldwide, 1996-2007	359.000 tonne of active matter	Global Status of Commercialized Biotech/GM Crops 2008 http://www.isaaa.org

* The product that is sprayed in the field contains several different compounds. The main one is the "active compound", or "active principle", which causes the pesti-

cide action. This compound is usually dissolved in a suitable solvent and can also contain other compounds to facilitate its application, depending on the apparatus to be used. The amount of active compound is generally a small percentage of the total commercial product.

** Web page:
http://www.ncfap.org/documents/2007biotech_report/Quantification_of_the_Impacts_on_US_Agriculture_of_Biotechnology_Executive_Summary.pdf

Figure 14.- Weed killer-tolerant maize sown over the crop residue of the previous year.

The reduction in tillage proved to be an unexpected benefit of herbicide tolerant crops, and has quickly spread among the farmers that plant them. In 2004, the cropland cultivated with herbicide tolerant soybean using low tillage techniques increased by 64%, which corresponded to 58% of the farmers that farmed this type of crop[150]. Cotton growing requires a large amount of different pesticides and insecticides, thus more significant reductions in these compounds are normally seen with respect to this crop.

As a result of the reduced need for insecticides, an important reduction in fuel has also been recorded, above all on big farms where spraying is done with tractors or light aircraft. Fuel savings can reach up to 60% per hectare and year, which in turn results in a subsequent reduction in greenhouse gas emissions. As indicated in the report of the European Group on Ethics in Science and New Technologies[151], over the first 10 years of the commercialisation of genetically modified crops (1996-2006), biotechnology farming reduced the use of pesticides by 286 million kg of active substance and enabled a reduction of 14,800 million kg of CO_2, which is the equivalent of eliminating 6.6 million cars over 1 year (approximately 25% of the cars registered in the United Kingdom).

Weed killer-tolerant plants use herbicides that are less aggressive for the environment, such as glyphosate and glufosinate, in addition to reducing production costs and increasing yields[152]. These herbicides easily degrade, thus surface runoff water is much less polluted than is the case with other weed killers. Below, we will see that they are less harmful to animal biodiversity. The downside is that the use of glyphosate has substantially increased over the last 12 years, giving rise to an increase in the species that can resist this compound[153]. As a result, agronomic practices have to be modified in many cases to combat them.

3.5.4.- Increase of productivity

Worldwide crop yield losses due to the attacks of insects can reach between 10% and 15%, while in the tropics losses can reach up to 30%. Nevertheless, for a lot of individual farmers, depending on their particular conditions, such losses can represent from 50% to 100% of their crops in severe infestation conditions[154].

The development of insect resistant crops, both edible (maize) and industrial (cotton), has made it possible to substantially reduce losses, above all in cases that are difficult to control, either because the insect attacks the plant root, or because the more harmful stages of the borers seek refuge inside the plant's stalk (corn) or bud (cotton), as can be seen in Figure 9. The genetically modified plant constantly produces this protein, thus the farmer has no need to watch out for the presence of harmful insects (which would have caused damage) in order to apply the control method of his choice. We should not forget that this bacterium has been used since the 1930's to control these farm pests in spray formulations (manually or mechanically) which contain a suspension of complete, albeit non-viable, bacteria. It is one of the few authorised insecticides for organic farming, as we have explained above. Before the commercial introduction of genetically modified crops in 1996, only 28% of farmers in Iowa and Minnesota used some type of chemical control against these borer insects[155], on account of their limited effectiveness.

Insect resistant crops enable the farmer to increase his maize crop yield by 10%, on average, in the USA[156]. Likewise, the controversial report on genetically modified crop by the *Union of Concerned Scientists*[157] confirmed that Bt maize crop yields can increase by over 10% those of conventional varieties, particularly under heavy infestations. In 2004 maize production in the USA increased by 49,000 t because of the cultivation of Bt maize[158]. An increase of 10% in rice production was recorded in China[159]. The increase of Bt cotton yields in developing countries are truly spectacular, reaching

33% in Argentina[160] and 25% in China[161]. Even though cotton is not edible, we mention it because it enables farmers to increase their income, and thus it exercises a very positive effect on improving living conditions.

As an additional and unexpected advantage, insect resistant crops reduce the target insect population in the corresponding adjoining conventional fields where the genetically modified crops are being grown. As a consequence, the need to used chemical insecticides on these other plots is reduced as well[162].

The development of nematode resistant potatoes doubled the yield obtained in Bolivia in field tests carried out by small farmers. It would, therefore, be possible to reduce the surface area used to grow potatoes in order to use it to produce other necessary crops[163].

Viral diseases, against which there are no effective conventional treatments, usually cause losses of 30% to 40%[164], which may even reach 80% of the crop in extremely serious situations. Virus resistant genetically modified crops enable substantial increases in yields. Indeed, the farming of papaya in Hawaii was about to completely disappear at the end of the 1980's as a result of a viral disease that quickly spread. The genetically modified papaya resistant to this virus was introduced at the end of the 1990's allowing the complete recovery of this crop. At present, over 50% of the papaya crop in Hawaii is genetically modified[165].

3.5.5.- Socio-economic considerations

Economic return is one of the pillars on which we hold sustainability to rest (Chapter 1) because a higher economic level makes the development of rural communities possible. As we have already pointed out, of the 13.3 million farmers in 2008 that planted genetically modified crops around the world, approximately 12.3 million were small farmers in developing countries[166].

Numerous studies have shown that the use of genetically modified seeds brings a greater economic return for farmers, regardless of the size of the farm, in spite of the fact that the cost of the seed is higher than that of conventional ones. This return, albeit variable in different countries, arises from the cost of pesticides and the increase in yield (Figure 15)[167]. Genetically modified seed price variability in different countries depends on whether the crops in question are patented, or not. Thus, in China competition with seeds developed by local, public funds did not allow to increase the price of patented ones.

Figure 15.- Economic return from insect resistant genetically modified crops in several countries

Horizontal axis (from left to right): seed cost, pesticide cost, yield, economic return, net profit.

(Taken from Raney & Pingali. 2007. Op. cit.)

In Spain, the only European country where genetically modified seeds (insect resistant maize) are sown, the increase in the average return between 2004 and 2006 was approximately €122/ha[168], which represents a 12% greater net profit than that made by conventional maize. Similar returns were also obtained in South Africa for insect resistant cotton and maize. The European Ethics Group, mentioned above, found that in 2006 the overall economic profits made by genetically modified crops amounted to €4,500 million, 54% of which was made by farmers in developing countries. In Europe, as in the rest of the world, two thirds of the profits made by genetically modified crops were shared between European farmers and consumers (reduced prices), with the remaining third corresponding to those who develop the seeds and commercialise them.

3.6.- Open questions on Environmental Considerations

It is not easy to study the long-term effects that genetically modified crops may have on the environment for the following reasons:

- The state of the ecosystem into which the genetically modified crop is to be introduced needs to be known *beforehand* (these would be the *initial* or basic *conditions* that allow to measure the changes that have occurred after the introduction of the genetically modified crop)
- The long-term effects due to continuing with traditional crops and agronomic practices would always have to be taken into account, an estimate that is frequently ignored because it is assumed that traditional practices would not cause any damage.

From the environmental perspective, the following are the questions that most often come up:

1. Premature development by the target insects of resistance to the Bt protein of insect resistant crops.
2. Effects on animal biodiversity caused by pesticide tolerant and insect resistant crops.
3. Possible adverse effects arising from the gene flow to wild species related to the genetically modified crop.

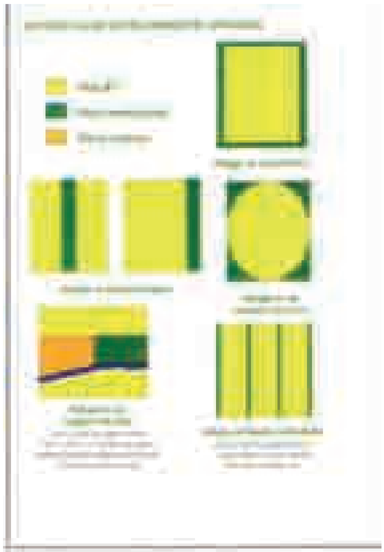
3.6.1.- Premature development of resistance to the Bt protein in target insects

It is quite reasonable to think that the generalised use of the Bt protein to control target insects will induce the development of resistance to this protein in species that are exposed to it, as has happened in the past with chemical insecticides.

This is why, in order to delay the appearance of Bt protein-resistant insects several measures are being taken:

- The setting-up of "refuges", or areas around the genetically modified plant field where the conventional crop variety is sown (and which is not treated with the insecticide) (Figure 16).The presence of the gene that confers Bt protein resistance in target insect populations will, thus, be diluted in these refuges. Setting up a refuge is compulsory for the farmer, and the company that commercialises the genetically modified seed must set up a monitoring programme.
- The use of genes that code for the Bt protein from different strains: these proteins, even though they have the same effect on the target insect, have somewhat different structures, thus the target insect is exposed to different compounds[169].

Figure 16.- Types of refuges:
- area sown with Bt maize;
- area sown with conventional maize;
- area sown with other crops;



At present no insects resistant to the Bt protein have been recorded in field situations, though they could do so in the medium term.

3.6.2.- Effects on biodiversity

Probably the most thorough assessment of the effects of glyphosate and glufosinate tolerant crops on weeds and animal biodiversity is the study known as the "Farm Scale Evaluations" carried out over 4 years (1999 – 2003) by the British Department for Environment, Food and Rural Affairs[170].

Glufosinate tolerant canola and maize, and glyphosate tolerant sugar beet, along with the corresponding conventional crops, were grown in 65 different commercial fields. A total of 283 field tests were carried out under commercial conditions using the most suitable agronomic practices on each crop. The findings of the study can be summarised in two, general conclusions:

- The amount of invertebrates associated with a certain crop exclusively depends on the herbicide used and not on whether the plant is genetically modified or

conventional: conventional maize (weeds are controlled with atrazine) turned out to be more harmful for invertebrate biodiversity than the genetically modified version (glufosinate was used as a weed killer)
- Genetically modified plants make weed management flexible, because they need only one third of the herbicide applications as do conventional crops.

It is quite obvious that the effects on animal biodiversity will depend on the type of genetically modified plant and the agronomic practices employed. Above we mentioned the generalisation of low tillage techniques with herbicide tolerant crops, which in turn reduce soil erosion and improve ecosystems development and management.

Insect resistant crops could turn out to be toxic for other different insects against which Bt toxin is not directed (non-target insects). In 1999, a short laboratory study published in the prestigious journal Nature indicated that the Bt protein was also toxic for the monarch butterfly (non-target insect)[171]. Over the next few years 6 field studies, carried out in different places, concluded that Bt protein was not damaging the populations of this butterfly[172].

After that time, a lot of studies have been published to determine whether the Bt protein has an affect or not on non-target insects. The general conclusion was that the Bt protein is only toxic for very specific species of insects. The already mentioned BEETLE Report, in which over 700 scientific publications regarding environmental questions are studied, concludes that the majority of laboratory and field studies consulted did not show any unexpected, adverse effect in the long term on non-target insects. An important lesson to be learned from this is that, even though negative effects may have been observed under extreme conditions in the laboratory, negative effects have not yet been observed in field situations.

A meta-analysis of 42 field experiments indicates that there is a greater amount of invertebrates (except for target insects) in Bt maize and cotton fields than in conventional fields in which these crops are grown and treated with chemical insecticides[173].

3.6.3.- Gene flow

Gene flow by cross-pollination among sexually compatible plants is an important mechanism in evolution, because it enables a plant to acquire new characteristics. Humanity developed farming by exploiting this natural system to improve food plants. Nowadays, controlled crossings continue being used to pass on desired characteristics from one plant to another.

The following questions arise in the context of the cultivation of genetically modified plants in open fields:

- Crossbreeding between the genetically modified plant and a closely related wild species:
  - Can the hybrid become an invading plant?
  - Can it become a 'super weed' that is difficult to eliminate?

The impact of the transfer of a given characteristic from a genetically modified plant to another conventional one (wild or cultivated) will depend on whether or not the characteristic in question confers a selective advantage on the hybrid in the ecosystem in which it is growing. Therefore, a hybrid that tolerates a particular type of herbicide will only have an advantage in those ecosystems in which that herbicide is used, but will be vulnerable in the presence of another one. An insect tolerant hybrid will have a better chance of reproducing itself in those places where that insect is an important pest, but not in others.

Depending on the region, there are wild species in Europe that are closely related to oilseed rape and sugar beet. The already mentioned BEETLE report concludes that in Europe the likelihood of more persistent hybrids being produced can occur in the case of these two herbicide tolerant genetically modified crops. Control of these hybrids is brought about by applying a different herbicide. In those ecosystems where the herbicide applied is the one tolerated by the genetically modified crop, control of hybrids may be more difficult.

The possible ease with which genetically modified crops could invade different ecosystems was studied before their commercialisation. In 1990, Crawley and coworkers[174] planted some genetically modified crops available at that time in 12 natural ecosystems (not in farmed plots): glufosinate tolerant canola and maize, glyphosate tolerant sugar beet and two varieties of insect resistant potatoes, along with their corresponding conventional crops. They visited the plots every year to determine their relative invasive potential. In the 4th year they found that all genetically modified and conventional crops had disappeared, except for the non-genetically modified potato, which held out until the 10th year, although with increasingly less intensity. These researchers concluded that domesticated plant varieties, genetically modified or conventional, depend on humans to survive in the environment.

CHAPTER IV: ARE GENETICALLY MODIFIED VARIETIES AND ORGANIC FARMING COMPATIBLE? SOME CONSIDERATIONS WORTHY OF REFLECTION

As we have seen, over the last decade legal regulations and directives of different authorities have taken up the idea of INCOMPATIBILIITY between the principles of organic farming and the use of genetically modified varieties. Nevertheless, we believe that as a result of this head-on, categorical rejection, there is no room left to reflect on what they might jointly offer to achieve a sustainable food production.

We will proceed to analyse some of the paradoxes with which we are faced from the perspective of the key factors that constitute food sustainability as described in Chapter I.

4.1.- The concept of natural as applied to food crops

As pointed out above, for most people organic crops are natural ones, because the idea that nature has made them as they are is widespread. For some people his concept also implies that they are traditional crops that go back to times earlier than our own, before we became "excessively dependent on the western world's technology" and that organic crops are not standardised to increase their productivity[175]. The application of the epithet "natural" to organic crops implicitly involves the rejection of the concept "increase in productivity" which, for many, points to an exclusively economic concern.

In our opinion, the stand held by organic agriculture that considers genetically modified crops as non-*natural* completely overlooks the following important facts that can be applied to all types of agriculture:

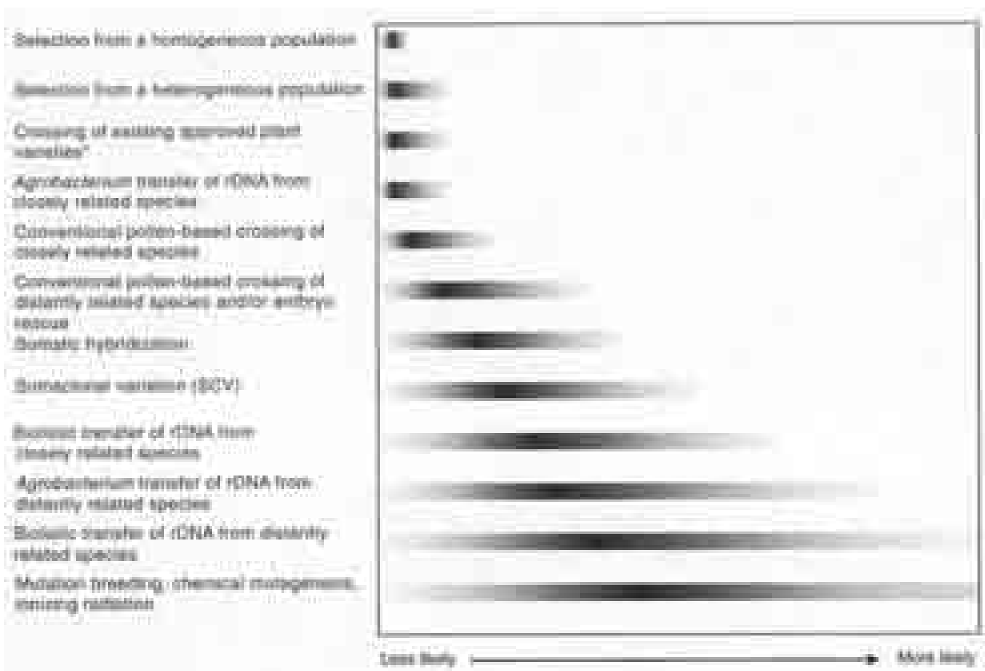
- Conventional crops, developed over the centuries since the Neolithic age, have undergone extensive modifications to their genomes during the domestication process (Figure 17).
- Crops developed by induced mutations (by radiation, or treatment with mutagenic chemical products), crossbreeding of different species followed by embryo rescue, and somaclonal mutations in *in vitro* cultures are considered conventional.
- As we have seen above, cultivated food crops cannot survive on their own in nature for very long without human intervention because during the domestication process the characteristics needed to survive in the wild were eliminated in favour of those that are suited to farming (Figure 17)[176]:

Figure 17.- Phenotypical differences between maize and its predecessor, teosinte, resulting from the profound changes introduced into its genome. In addition to radically changing the architecture of the plant, the teosinte ear is flexible to favour seed dispersion, whereas that of maize is rigid to facilitate its harvesting.

Some authors, in their attempt to explain why they reject the use of genetically modified crops in organic farming, claim that the concept of *naturalnes*s implies the integrity of the plant as such[177], implying that this integrity refers to that of its genome. Nevertheless, the genome of conventional crops is profoundly modified, as we will show below. For example, Ammann remarks in the aforementioned reference that in the most frequently grown varieties of wheat (which are also used in organic farming) 58 main chromosome reorganisations alone have been characterised. Several chromosome translocations and inversions have been characterised in most crops, in addition to duplications of the number of chromosomes. As we have pointed out, the profound restructuring of the genome of modern conventional crops over the course of hundreds of years is very frequently ignored.

Recently, several authors have published in-depth studies on the genome of plants obtained by classic crossings, by induced mutagenesis, and by genetic engineering techniques. In these studies transcriptomic (analysis of the set of genes expressed, or active, at any given time) and metabolomic (analysis of the set of metabolites present in a cell or an organism at a given time) techniques have been used. Several authors have compared, on the one hand, different conventional varieties of rice or wheat with one another, and on the other hand, genetically modified varieties with the conventional ones from which they were obtained[178]. Figure 18 summarises the extent of the genetic modifications introduced into a plant's genome by different techniques.

Figure 18.- Magnitude of the genetic modifications introduced by different conventional and transgenic technologies (taken from: Committee on Identifying and Assessing unintended effects of genetically engineered foods on human health. 2004. Safety of Genetically Engineered Foods. National Academies Press. page 64)



From the top down:

- Selection from a homogenous population.
- Selection from a heterogeneous population.
- Crossing of existing approved plant varieties.
- Agrobacterium transfer of DNA from closely related species.
- Conventional pollen-based crossing of closely related species.
- Conventional pollen-based crossing of distantly related species and/or embryo.
- Somatic hybridization.
- Somaclonal variation (SCV).
- Biolistic transfer of DNA from closely related species.
- Agrobacterium transfer of DNA from distantly related species.

- Biolistic transfer of DNA from distantly related species
- Mutation breeding, chemical mutagenesis, ionising radiation.

In all cases it has been confirmed that the alterations to the genome of conventional plants obtained by classic crossbreeding and by induced mutagenesis are much greater than those of the same plants transformed by genetic engineering techniques. That is to say, the genomic differences between two different varieties of a conventional crop obtained by classic crossbreeding (let us not forget that in crossbreeding the two full genomes of the parent organisms are combined at random) are much greater than those between a conventional variety and the genetically modified one derived from it.

In light of these data, it seems impossible not to conclude that genetically modified plants are as natural, or as artificial, as conventional ones, and therefore, as organic ones for that matter.

4.2.- Conventional improvement of crops

The history of agriculture is normally summed up as a process in which two driving forces, two major goals, have guided scientific-technological advances:

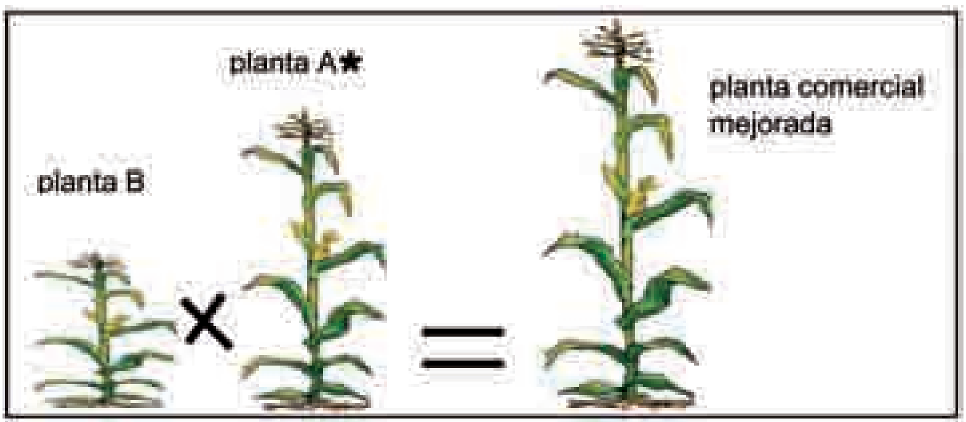
1) To facilitate the task of those who work in farming and stockbreeding by tool development;
2) To increase yield, seeking greater productivity, and if possible, at less cost. The search from an improvement in animal and plant varieties has been one of the ways to meeting the 2nd objective primarily.

Conventional crop improvement methods are all of those that do not involve the use of genetic engineering. The seeds that are used in organic farming are produced by conventional methods.

To improve any crop by conventional methods, one needs to have a plant with a characteristic of interest and which is sexually compatible -either wholly or in part- with the plant one wishes to improve. We briefly explain below how a conventional plant acquires the target characteristic. In our opinion, it is very important to understand how a plant can be improved by conventional techniques to duly appreciate crop improvements brought about by genetic engineering.

Production technologies for all commercial crop varieties, conventional or transgenic, use *crossbreeding* at some stage, that is to say, the sexual crossing between two compatible plants, in order to pass a particular characteristic from plant A to plant B (Figure 19). The difference between conventional and genetic engineering technologies lies exclusively in how the desired characteristic is introduced in plant A.

Figure 19.- Crossbreeding of a plant that possesses the desired characteristic (plant A) with the plant one wishes to improve (plant B).



*characteristic introduced by:

- Conventional methods: mutations of all types, somaclonal variations, treatments with colchicine, cell fusions (protoplasts), etc.
- Genetic engineering (transgenesis).

The desired characteristic can be introduced in conventional crops by using one, or several, of the following methodologies:

- Spontaneous mutations[179]: quite often recognised in agronomic practices. Several mechanisms may occur, the explanation of which fall beyond the scope of this paper. For example, an organic cauliflower (with a greater concentration of β-carotene) (Figure 20A) can be easily spotted in the field; or a maize that becomes tolerant of a particular frequently used herbicide can be identified on treating the field with that herbicide because it survives.
- Mutations induced by any of these methods:

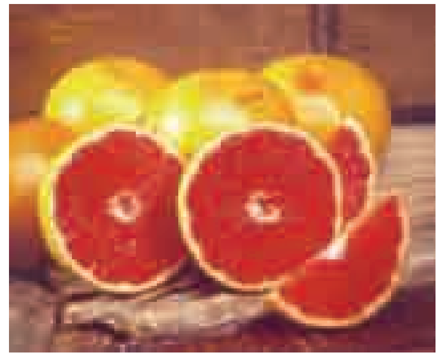
- Ionising radiations: γ or X–rays are the ones most frequently employed. Figure 20B shows a deep pink grapefruit, the *Rio Star* variety, obtained by irradiation (it accumulates β-carotene) along with a non-irradiated variety. *Rio Star* was obtained by irradiating the *Star Ruby* variety with slow neutrons, obtained in turn by irradiating a variety that appeared spontaneously in Texas in 1929. *Rio Star* was commercialised in 1984[180].
- Treatments with mutagenic chemical products. Table 9 indicates the most frequent mutagenic treatments (by irradiation or chemical products) used, along with some examples of the varieties obtained.
- Cosmic radiations and the absence of gravity. For over 20 years seeds have been sent into space[181]. In 2005, China had obtained over 50 new varieties and had approved the large-scale planting of 43 of these species. At that time it was developing a further 200. They claim that the vitamin content of these varieties is practically 300% greater than that of varieties that have not been sent into space. Recently, varieties of giant vegetables have been obtained by this method (Fig. 20C: space vegetables).
- Somaclonal variations. These are mutations that appear in plant cells and tissues grown *in vitro*. The presence of different chemical compounds in the culture environment during the adaptation of the plant cells to the in vitro culture conditions, the induction of callus formation, the formation of embryos and the regeneration of the plant induce the appearance of mutations, which in many cases are useful and can be inherited[182].

• Alteration of the number of chromosomes, either appearing spontaneously, or induced by treatments with particular chemical compounds, such as the alkaloid colchicine (Figure 20D: the autumn crocus). Example: the seedless watermelon is the result of a cross between a diploid plant (2 sets of chromosomes; normal plant) with a tetraploid plant (4 sets of chromosomes) obtained by treatment with colchicine[183].
• Somatic crossbreeding, or protoplast fusion, to obtain polyploid plants[184].
• Forced crossbreeding of different species followed by the rescue of the naturally non-viable embryo and later development of the plant by *in vitro* culture techniques.

As a result, the plant genome is modified spontaneously in a few cases, or artificially in all the rest, though none of these techniques is genetically engineered. Spontaneous mutations (by different mechanisms), duplication of chromosomes, and crossbreeding between different species (a rare event) occur in nature, but none of the others.

Figure 20: varieties of vegetables and fruit obtained by different mutations (A – C), and autumn crocus (D).

A.- Spontaneous mutation:
Orange cauliflower



B.- Radiation induced mutation:
Rio Star grapefruit

C.- Cosmic radiation induced mutation and microgravity: “Space” pumpkins

D.- Autumm crocus from which colchicine is extrated

In 1928 Stadler published an article in Science on the obtaining of barley mutants after irradiating the seeds with X-rays and with the then recently discovered radium[185]. Since then, many professionals working on the development of new crop varieties have used, and still use, any of these techniques (mainly irradiation) to obtain mutations that give rise to desirable characteristics. Afterwards, the desirable characteristics are transferred by sexual crossbreeding to cultivated varieties of interest[186].

The characteristics most frequently developed by induced mutations are: plant architecture (size, above all dwarfism), ripeness, resistance to diseases and pests, resistance to abiotic factors such as drought and salinity, modification of the profile of oil fatty acids and increase in the content of oil, size and quality of cotton granules, improvement in the malting quality, etc.

The FAO has developed a joint programme with the International Atomic Energy Agency[187] to help member states in the use of nuclear techniques and other related biotechnologies to improve the development of sustainable food security strategies. Its database contains nearly 2,600 crop varieties, 25% of which correspond to ornamental plants. Among the 175 species that have been improved by these techniques are some of great importance for the world economy, such as, rice, wheat, barley, cotton, the chickpea (garbanzo bean), oilseed rape, sunflower, banana, sesame seed, sorghum, peanut, pear, and grapefruit. As indicated on the above mentioned web page, only those varieties voluntarily declared by their producers to have been obtained by induced mutations are included in the database. It is reasonable to conclude that the total number of crop varieties obtained by induced mutations is substantially greater than that which appears in the database, because it is quite likely that the way in which a lot of crops have been obtained is not communicated to avoid rejection.

Table 9.- Mutagenic treatments used to obtain new commercial varieties

Tratamiento[a]	**Algunos ejemplos**
Radiaciones	
rayos	arroz Calrose76
rayos X	avena Alamo-X, alubias Seafarer, alubias Seaway
neutrones	pomelos Rio Red, Star Ruby; trigo Lewis.
radiaciones sin especificar	maíz Clearfield (resistente a herbicidas); pera japonesa resistente a enfermedades; colza comestible (bajo erúcico y bajo glucosinolatos)
Compuestos químicos	
etilmetano-sulfonato	lechuga IceCube, MiniGreen
azida sódica	trigo Above
colchicina y cruzamientos interespecíficos	triticale
colchicina	sandía sin pepitas
Variaciones somaclonales y gametoclonales[b]	tomate, pimiento

a AM Van Harten. 1998. "Mutation Breeding: Theory and Practical Applications". Cambridge University Press, page 20

b Chrispeels & Sadava, 2003. Op. cit.

In the recent FAO/IAEA database analysis carried out by Ahloowalia and coworkers, over 70% of the varieties obtained were directly commercialised by multiplying the selected individual mutant. The rest were obtained by crosses between the individual mutant and other commercial varieties[188]. Irradiation was used in 89% of the cases, with gamma rays being used to develop 64% of the varieties, whereas X-rays were used on 22%.

Literally millions of plants obtained by any one of these methods are planted every year to select those with the desired characteristics. For example, at the Carlsberg laboratories in Copenhagen in 1995, the research team led by Dr. D. von Wettstein analysed 18.5 million barley plants obtained by mutagenic treatments to select the one that did not produce chill haze in beer on cooling[189].

Organic farming accepts all of these techniques to obtain new varieties, except for genetic engineering, as we have mentioned above. As an example, the label on a packet of triticale flour from an organic farm -*Bob's Red Mill Natural Foods* (in Milwaukee, Oregon, USA) reads: "Triticale is a hybrid grain- a cross between wheat and rye. On average it contains 28% more protein than wheat and all the essential amino acids, thus being a more complete source of protein than its parent grains. It has an interesting nutty flavour and is high in fibre. Because Triticale Flour has inherited the best qualities of its predecessors -wheat and rye- and has a delicious flavour, it needs to be discovered by you right now". The label does not say that it has been produced using colchicine, and that wheat and rye cannot be crossed in nature[190].

The varieties obtained by conventional mutagenic treatments have not only been commercialised in the western countries such as the USA, Canada, numerous European countries, Japan and Australia, but also in a lot of developing countries such as China, India, Pakistan, and other Asian nations (review by Ahloowalia cited above). None of these varieties, nor the food obtained from them are labelled as being "obtained by induced mutagenesis".

As we will go on to mention below, to date no law has been enacted that mandates the assessment of these crops before their commercialisation, neither from the point of view of their safety for humans, nor for the environment.

4.3.- Non-genetically modified food assessment before its marketing

For consumers in any part of the world, safety is the most important attribute for any foodstuff. In many cases conventional foods have been obtained with the excessive use of chemical pesticides. Concerned that these foods may contain unacceptable concentrations of these compounds has recently driven up the demand for organic foods, above all in the wealthiest countries in the world. Organic food is widely believed to be significantly healthier and safer than conventional food and a large amount of consumers are prepared to pay substantially higher prices for it. According to the news recently published in the Spanish daily newspaper "El Mundo”[191], the organic food world market amounted to €34,300 million in 2007 (some US $48,000).

Nevertheless, organic crops and food are not subject to any assessments as regards their safety for consumers (or for the environment), nor are their supposed nutritional characteristics checked before their commercialisation. As far as we know, there is no legal provision in any country in the world that mandates the assessment from a nutritional, environmental or agronomic perspective of organic or conventional crops and food.

The obligation to assess genetically modified food before its commercialisation, but not organic food, (nor conventional food for that matter), shows that the process through which the crop has been obtained is deemed to determine its characteristics. Nevertheless, this is not the case. We have said above that the modifications in the genome of plants introduced by conventional techniques are in general more extensive than those introduced by genetic engineering. This tells us that the final product is what really matters, because that is what people eat. We hold that, if genetically modified crops are assessed, then so must the others. Consumers have a right to receive truthful information on the food that is on sale, whatever the procedure currently used to produce it.

Companies that develop seeds obviously assess the agronomic aspects to ensure that the crop will grow well in those conditions for which it has been developed. We have come across some references in the scientific literature to several conventional crops that had to be withdrawn from the market as a result of problems for consumers or farmers. The Lenape potato, introduced in 1967, contained fewer sugars, more solids and better properties to make commercial chips[192] than other varieties, in addition to being resistant to the attacks of some insects (it was obtained by a cross with a wild species from the Peruvian Andes)[193]. Practically immediately after its commercialisation it was seen to have high levels of glucoalkaloids[194], which are natural potato toxins. In spite of its toxicity, this potato variety was used to develop a further 13 varieties[195].

Several varieties of squash were commercialised in 1981 and 1982 that proved to contain high concentrations of cucurbitacin, a toxic substance for cells that may cause diarrhoeas and severe stomach pains[196]. At the end of the 1980’s a variety of celery highly resistant to insect attacks (it had been developed from a cross with a wild species) was introduced. It caused serious skin problems to those who handled it (during harvest, packing and commercialisation)[197]. It was shown that this new variety possessed a high concentration of psoralens, which are mutagenic compounds that substantially increase skin sensitivity to light, causing dermatitis if their concentrations are sufficiently high.

Even though it was not indicated anywhere that these crops were organic, all of them had been obtained by crossbreeding (a method acceptable to organic agriculture) between wild varieties and those of commercial interest. In all cases without exception, they all proved to be toxic for people after their commercialisation and sale to the general public.

Some considerations related to the quality of organic goods are discussed below.

4.3.1.- Residue of synthetic pesticides in food

On account of the fact that organic agriculture does not use synthetic pesticides (though it does use chemical products as has been indicated above), the concentrations of chemical pesticides in organic foods are significantly lower than those to be found in conventional foods, as indicated in the EFSA report published in June 2009[198]. This report presents data from 74,305 food products from European Union countries, in which 218 different pesticides were analysed. The maximum pesticide levels authorised in the European Union are the same for all types of food, whether it be produced by organic, conventional or genetically modified technologies.

Even though this report has not specifically studied organic food, some countries have provided data on the concentration of pesticides in such foodstuffs. Of the 2,900 organic products analysed (cereals, fruit and vegetables, and processed products), in 1.24% pesticide levels are in excess of the maximum allowed, while this level is surpassed in 3.99% of the conventional crops (71,400 analysed overall)[199]. In the processed organic food category, 4.21% exceeded the authorised limits, but only 0.62% of the organic cereals and 1.09% of the organic fruit and vegetables showed levels over authorised limits.

It is worth pointing out that in the EFSA report the level of pesticides found in 96.01% of all the foodstuffs analysed falls below maximum authorised levels, probably due to the fact that the conditions for the use of insecticides are specified with great rigour and their concentration in food is subjected to strict monitoring. For that very reason, referring to a recently published comparative study on the nutritional properties of organic and conventional foods, the Executive Director of the FSA in the United Kingdom said last August that "the use of pesticides in either organic or conventional food production does not pose an unacceptable risk to human health and helps to ensure a plentiful supply of food all year round"[200]. This explains why in the comparative study mentioned above, pesticide levels have not been analysed in either organic, or in conventional, foodstuffs.

Other authors[201] have found lower pesticide levels in organic food than in conventional food, even though the amount was well below authorised levels in both cases.

4.3.2.- Concentrations of compounds of nutritional value

Quite often, social agents, including mass media, politicians, consumer association representatives and NGO's among others, primarily relying on the fact that organic agriculture does not use synthetic chemical products, refer to organic food as being "*of high nutritional quality*". This expression implies that foods obtained by conventional methods do not reach the same level of quality. Nevertheless, scientific data to back up this general perception of the goodness and safety of such foodstuffs are quite scarce.

European Regulation 843/2007 and the US Department of Agriculture -in charge of the National Organic Program, as we have pointed out above- state that the organic classification does not say anything about the nutritional properties of the crop in question, but rather refers only to its production method.

MD Raigón, in his book "Alimentos ecológicos, calidad y salud" clearly indicates that the results of the comparative analyses of the concentration of particular nutrients in food obtained by organic and conventional production systems are highly variable and contradictory[202]. This is mainly due to several factors that affect the concentration of nutrients and sapid compounds, such as crop variety, climate in production areas, soil, the state of ripeness, transport, and storage, etc.

The only valid way to study possible differences in the concentrations of any compound is to know exactly the production methods employed to ascertain their organic status[203]. To do so, conventional and organic food (same varieties) must be grown on plots with the same soil by conventional, or organic, agronomic practices, as appropriate.

At the end of July 2009, the British Food Standards Agency (FSA) published an extensive bibliographical review of the scientific literature published in English about the contents of different nutrients and other components and the different effects on health that organic foods are supposed to have as opposed to conventional foodstuffs[204]. This comparative study covers 162 articles published over the last 50 years in scientific journals with external reviewers (a total of 3,558 comparisons covering 137 crops) and which meet the strict specified quality criteria to accept their findings including, among others, a clear definition of organic farming practices[205]. Taking into account all the selected results, the statistical study of all the data indicates that there are no significant differences between organic crops and conventional ones as regards the content of the following nutrients, and other compounds: vitamin C, calcium, phosphorous, potassium, total soluble solids, titratable acidity, copper, iron, nitrates, manganese, ash, specific proteins, sodium, plant non-digestible plant polysaccharides (fibre), β-carotenes, and sulphur. When only those findings of articles that meet even more strict quality criteria were included in the meta analysis, the following differences were found: conventional crops have higher levels of nitrogen, whereas organic crops have a higher phosphorous concentration and a higher titratable acidity level[206].

The executive summary clearly indicates that there are limitations in the design of the published comparative studies, saying that the differences may be due to differences in crop management and/or soil quality, and that the conclusions are based on currently available data. The Executive Director of the FSA published an open letter concerning this study as a result of several interpretations that had appeared in the mass media concerning the results of the report. In it he said that "the important message from this report is not that people should avoid organic food but that they should eat a healthy balanced diet and, in terms of nutrition, it does not matter if their diet is made up of organic or conventionally produced food"[207].

In our opinion, this FSA study is the most rigorous one we have come across due to its scope and the quality criteria employed by its authors to systematically include, or not, the findings published in the scientific literature. We also wish to highlight the fact that findings published in journals (or other publications) that do not have external reviewers were not included.

There are also recent reviews available in scientific literature, though more limited in scope, in which the concentration of certain nutrients in organic and conventional foods is compared. For example, Danish researchers did not find significant differences in the vitamin, mineral and antioxidant content in organically and conventionally grown vegetables and apples[208]. Moreover, these authors carried out feeding studies on animals over 2 years without finding any significant differences in the assimilation of these compounds. Similar studies carried out on humans indicate that even though organically grown tomatoes possessed a higher vitamin C and polyphenol content than conventionally grown ones, no significant differences were found in the antioxidant levels in plasma after the intake of some 100 g a day of organic tomatoes and tomato sauces or conventional ones over 3 weeks[209]. In another study, organic tomatoes were found to have a greater concentration of soluble solids and titratable acidity in the juice, an important feature when it comes to making sauces. They had better flavour and texture than conventional ones, whereas the latter had better colour and their juice preserved greater concentration of vitamin C and polyphenols after being cooked in a microwave oven[210].

Magkos and coworkers (in the article mentioned above) concluded that nitrophilic organic foods (broad leaved vegetables) contain a lower amount of nitrates than conventional foods, though no significant differences have been found in the non-nitrophilic food. The negative or positive importance of the nitrate content for human health is still being debated.

In conclusion, we must point out that any differences in nutritional quality between organic and conventional food must not be exaggerated, because these differences are not presently endorsed by reliable scientific data. In some cases it has certainly been observed that the concentration of some vitamin, or mineral, is greater in organic crops than in conventional ones. Notwithstanding, this is true the other way around in other cases. That is to say, the nutritional quality of organic crops and that of conventional ones is, in general, wholly comparable, and generalisations saying that the former are healthier than the latter cannot be made.

4.4.- Consequences of the rejection of genetically modified crops and responsibility for present and future generations

The rejection of genetically modified crops in Europe is currently giving rise to important consequences, among which the following are worthy of special mention:

- the loss of competitiveness in plant biotechnological research, bearing in mind that Europe was a pioneer in this field at the beginning of the 1980's.
- the moving to the US of the research laboratories of several multinationals.
- the loss of competitiveness of the farming and livestock sector in Europe.
- the influence of the European attitude in the backwardness of agricultural development in Sub-Saharan Africa, among other places.

Considering the nature of this paper, we will expand on the last two points in greater detail.

4.4.1.- Loss of competitiveness of European farmers and livestock breeders

As a result of the rejection of genetically modified crops, European agricultural productivity is at present 15% below that of the USA, in spite of the fact that in 1995, the year before the commercialisation of genetically modified crops worldwide, both were on a par[211]. Consequently, over the last few months voices are being raised in Europe in protest at the fact that this may have very negative consequences for food security in EU countries. Furthermore, the European Group on Ethics in Science and New Technologies[212] acknowledges the need that European primary food, fibre and plant feed production be competitive on the world market, and therefore, admits the need for innovation in this sector. The loss of competitiveness may give rise to a gradual abandonment of farming activities with the subsequent increase in food imports and food prices. In short, it will bring about an increase in the percentage of the population at risk of suffering from a food deficit.

The FSA report mentioned above explains that big food distribution chains are paying up to 20% more for food that does not contain genetically modified elements. Even though some are authorised in Europe, the products that carry over 0.9% must state this on the label[213], as we have already explained above. Considering consumers' rejection and pressure from ecologist groups such as Greenpeace and Friends of the Earth, they have chosen not to include these food items in their lines[214].

In the words of the President of the Spanish Young Farmers Association (ASAJA),

"*the European ban on genetically modified organisms will see EU farmers left out of the world market, immersed in an absurd situation whereby they are not allowed to grow these varieties, but they are allowed to import them*"[215].

As we have indicated in Table 4, in Europe only the growing of insect resistant maize is permitted, even though soybean, maize, canola and sugar beet can be imported for use as food and feed.

The main problem for the livestock sector is the "zero tolerance" level for genetically modified crops that are authorised in other countries, but have yet to be authorised in the European Union. As a result of the gap in the authorisation processes in different countries (known as "asynchronic approval"), the raw materials for feed can only contain the genetically modified crops authorised in Europe, rejecting all those that contain traces of other non-authorised components. This has happened several times. The one that received most media attention was the LL601 rice incident in 2006, most likely because it was detected in rice grown for human consumption. Considering that in Europe the number of genetically modified crops is substantially lower than in other countries, these situations are becoming increasingly more frequent.

As stated in the report entitled *EU Policy on GM soya-tolerance threshold and asynchronic approval*[216], even though this clause significantly affects the European food industry, the livestock sector is the main one affected because it depends to a great extent on the importation of soya as a main source of protein for feed production. The use of alternative protein sources, such as peas or soya without genetically modified content, will no doubt give rise to an important increase in meat production costs, which in turn will have an important affect on its accessibility to the economically weaker sectors of society. Two years ago the European Commission acknowledged that this clause was contributing to the increase in food and feed prices and to the loss of competitiveness of the European livestock sector[217], without anything having been done to remedy the situation.

The British Department for Environment, Food and Rural Affairs, a country that imported 3 million tonne of soya for animal feed from Brazil and Argentina in 2007-2008, estimates that the price of meat, meat products and poultry could increase by 20%, with an even larger increase being expected in the pork sector[218]. The British Secretary for the Environment urged Brussels to speed up the approval process for these varieties, stating that "if GMO's can be a positive help, society must have the chance to make use of this technology if, moreover, a growing number of countries are opting for these products every year"[219].

4.4.2.- Influence of the European anti-GMO attitude on the development of farming in Africa

The effect of rejecting genetically modified organisms in Europe extends beyond its frontiers and is exercising a serious impact on agricultural development in developing countries, mainly in Africa, as Paarlberg claims in his recently published book, *Starved for Science - How biotechnology is being kept out of Africa*. This continent is the only one that did not benefit from the Green Revolution as can be inferred from Table 10.

As we mentioned in relation to Figure 2, Sub-Saharan Africa is the only part of the world in which the percentage of undernourished population in 2003 remains on the same level as that recorded for 1969, which means that the number of undernourished people has substantially increased in reality. The food production situation over the last few years in Sub-Saharan Africa is summarised in Table 11 and Table 12 below.

Global crop productivity in Africa has increasingly fallen to the extent that in 2005 it was 19% less than in 1970[220]. Between 1966 and 1970, the African continent was, on the whole, a net exporter of food, but by the end of the 1970's it was importing 4.4 million tonne a year, and by 2002 Sub-Saharan Africa was importing 19 million tonne of food (in grain and grain equivalents), over 15% of which came in the form of humanitarian aid. Table 12 shows the yield of maize crops for several African countries and other countries around the world.

Table 10.- Percentage of land planted with high yield seeds

Country	1970	1998
South América		
wheat	11	90
rice	2	65
Asia		
wheat	19	86
rice	10	65
África		
sorghum	0	26
millet	0	14
cassava	0	18

Taken from the UN 2001 Report on Human Development entitled, *Making New Technologies Work for Human Development*.

Table 11.- Some data on the state of agriculture in Sub-Saharan Africa. Adapted from R. Paarlberg, (2008. Op. cit.).

	Africa	Europe	The United States of A
population that makes its living from agriculture	Approximately el 70%	Less than 5%	Less than 5%
Average size of farms	80% have less than 2 ha.	Big farms	Big farms
Use of fertilisers	Less than 9 Kg./ha.	117 Kg./ha.	117 Kg./ha.
Mechanisation	2 tractors/1.000 farmers	The United Kingdom: 900tractors / 1.000 farmers	
Aded value per farmer	(1998): $ 370 and falling	France (1998): $ 37.000 and rising	
Average income of farming families	Kenya (2000): $ 553 Zambia: $ 122		Higher than the average income of non-farming families (2007)

Low agricultural productivity in Africa arises from a number of factors among which the following deserve special mention: the generalised use of rudimentary farming implements (hoes and sickles for example), the impoverished land due to the lack of nutrients that is worked by the majority of small farmers, the impossibility of acquiring fertilisers, insecticides and improved seeds due to their cost, the practically exclusive dependence on rain to irrigate their crops, and the widespread use of traditional techniques that have not been improved as a result of the lack of the required agronomic knowledge. In addition to these aspects that are directly related to agriculture, we must also take into account political instability and periodical conflicts, the AIDS epidemic, and the distortion of international markets as a result subsidies and tariffs in developed countries[221].

Table 12 – Average productivity of maize crops in different countries in 2004. Data taken from M. Demont & E. Tollens (2004) Annals of Applied Biology 145, 197-207.

	AREA (Million Ha)	%	Yield (Tonne/Ha)	Production (Million tonne)	%
Africa	26.0	18.7	1.6	42.6	7.0
Kenya (2005)[a]			1.6		
Malawi (2005)[a]			0.8		
Asia	43.1	31.0	3.8	163.8	26.8
Canada	1.2	0.9	7.3	8.7	1.4
EU – 15	4.3	3.1	8.8	38.1	6.2
Austria	0.2	0.1	9.4	1.7	0.3
Belgium-Lux.	0.0	0.0	10.6	0.4	0.1
France	1.8	1.3	8.6	15.2	2.5
Germany	0.4	0.3	8.6	3.3	0.5
Greece	0.2	0.2	9.3	2.0	0.3
Italy	1.1	0.8	9.4	10.1	1.6
The Netherlands	0.0	0.0	8.6	0.2	0.0
Portugal	0.2	0.1	5.8	0.9	0.1
Spain	0.5	0.3	9.5	4.3	0.7
South América	17.2	12.4	3.4	59.0	9.6
USA	28.7	20.6	8.5	244.4	10.0
Others	18.6	13.4	3.0	55.2	9.0
World	139.0	100.0	4.4	611.7	

[a] Data taken from Paarlberg, 2008. Starved for Science. Page 81.

A lot of small farmers from developing countries compulsorily practice a different type of organic farming from that which is practiced in developed countries. Yields are too low to provide surplus material to be returned to the land. Badly fed livestock produces low quality manure which is used as fuel, and not as fertiliser. This leads to soil impoverishment, followed by its swift degradation. Pests are not effectively controlled. According to R. Labrada Romero, an FAO expert in weeds, small African farmers (80%

of whom are women and children) need to work continuously, day in and day out, to remove weeds, which means that a single family cannot manage any more than 1.5 ha[222] As a result of all the foregoing, crop yields are extremely low[223].

Moreover, chronic under nourishment must be added to this low yield due to the lack of the amounts of necessary vitamins and minerals: the "hidden hunger" we referred to before.

Already in 1999, the report of the Nuffield Council on Bioethics entitled *The use of genetically modified crops in developing countries* concluded that:

"... on the basis of the available evidence, there is a moral imperative to make GM crops readily and economically available to people in developing countries who want them".

Moreover, the follow-up paper published by the same organisation in 2004 stated:

".... GM crops can contribute to substantial progress in improving agriculture, in parallel to the (usually slow) changes at the socio-political level. GM crops have demonstrated the potential to reduce environmental degradation, and to address specific health, ecological and agricultural problems which have proved less responsive to the standard tools of plant breeding and organic or conventional agricultural practices. Thus, we affirm the conclusion of our 1999 Report that there is an ethical obligation to explore these potential benefits responsibly, in order to contribute to the reduction of poverty, and to improve food security and profitable agriculture in developing countries"[224].

Further on it states:

"... The moral imperative for making GM crops readily and economically available to developing countries who want them is compelling. The Working Group recommends a major increase in financial support for GM crop research directed at the employment-intensive production of staple foods together with the implementation of international safeguards" (Page 93).

The 2001 UN Report on Human Development insists on the need to assess the use of genetically modified organisms, while also considering other alternatives, including the option of "maintaining the status quo":

"All possibilities of action should be compared, including non-action, with respect to improvement, in human health and nutrition and the possibility of accessing an adequate diet, in an economically effective and environmentally sustainable manner"[225].

The 2004 FAO Report, The State of Food and Agriculture - *Agricultural Biotechnology, Meeting the needs of the poor?,* claims that biotechnology has enormous potential to meet the needs of farmers with scarce resources[226]. Genetically modified crops can be quite easily adopted by farmers because the technology is enclosed in the seed, and this is the easiest manner of transference regardless of the scale of agricultural production. It acknowledges the fact that some genetically modified crops, such as insect resistant cotton, are producing important economic returns for small farmers, as well as bringing about significant social and environmental benefits.

In spite of the recommendations of the prestigious Nuffield Council on Bioethics, the clear and overwhelming statements of the FAO report, and of others like the 2001 UN Report[227], a strong rejection to genetically modified crops has become widespread all over Sub-Saharan Africa. This rejection according to Paarlberg[228] is influenced to a great extent by the European attitude against these foods, which is leading African countries to think that such foods will surely bring some problem for people or the environment, despite what scientific organisations may say to the contrary.

It is no secret that many prestigious environmental NGO's, and ones that enjoy great standing among European citizens, are wholly against genetically modified crops, postulating risks that have not materialised over 13 years of the planting of such crops, a practice that is becoming increasingly widespread around the world. After the publication of the 2004 FAO Report, over 650 organisations around the world have sent a letter to the FAO Director expressing their disagreement for the support shown therein to genetically modified crops[229].

Anti-GMO attitudes have given rise to a significant reduction in international aid to increase agricultural productivity in Africa and to promote research and development of appropriate crops in agronomic and nutritional terms[230]. The European regulation model for genetically modified crops has been adopted by many African governments upon the advice of NGOs to avoid rejection of their exports to Europe. The European Union is a powerful economic block with some 480 million consumers, the majority of which live comfortably, and "the customer is always right"[231]. It so happened that Zambia and Zimbabwe, during the famine of 2002 caused by several years of continuous drought, rejected humanitarian aid that contained genetically modified maize not to lose their "GMO-free" status and thus maintain their lucrative food export market -which included organic foodstuffs- to Europe.

In 2007, the African Union organised a High Level Panel to study the application of modern biotechnology. Made up of representatives from many African states, as well as from Canada and the USA, its report clearly stated that African nations cannot afford the luxury of doing without new farming technologies. All new technologies need to be applied with sufficient care in order to protect human health and the environment[232]. Nevertheless, this report remains unapproved by the African Union itself, probably because its stance as regards multinational seed producers is not critical[233] as could be expected from the general attitude professed by its governments.

Many philanthropic foundations[234], the United Nations and the governments of some European countries[235] have gradually reduced their contributions to improve agricultural productivity on the African continent. Only recently, after the spectacular rise in food prices because of great scarcity over the last 2 years, the Director of the FAO, Jacques Diouf, has stated the need to increase agricultural productivity in Sub-Saharan Africa[236].

Over the last two or three years several public-private consortia have been set up in which philanthropic foundations, multinationals, and research centres participate to boost the development of crops that are specifically adapted to African needs. Among these philanthropic foundations, we can mention the Bill & Melinda Gates Foundation and the Rockefeller Foundation.

The genetically modified characteristics that are preferably being researched in developing countries are, above all, those that enable the growing of local varieties with the lowest possible amount of agrochemical products (high cost) (Table 13)[237]. The set of characteristics that confer resistance to viruses, diseases and insects represents 66% of the crops undergoing development. Among these we can highlight the following: rice, maize, sorghum, cassava, yam or sweet potato, local vegetables, eggplant, potato, tomato and banana.

Table 13.- Some genetically modified crops being developed in Africa

Genetically modified characteristic	Percentage
virus resistance	27
insect resistance	26
fungi resistance	10
bacteria resistance	3
agronomic characteristics (including drought tolerance)	12
herbicide tolerance	5
Improving product quality	5

We are aware that the European anti-GMO attitude and the extremely strict regulations to which it has given rise in Europe and Africa alike, is due, in part, to the practices of multinationals, to the patent system and to international trade. These aspects, which in our opinion need to be fully modified, exceed the scope of this paper, though they directly affect the responsibility of developed nations towards the economically weaker ones.

CHAPTER V: TOWARDS THE PRODUCTION OF MORE SUSTAINABLE FOOD: THE USE OF GENETICALLY MODIFIED SEEDS IN ORGANIC FARMING

We have seen that organic food is equally nourishing as conventionally grown food, as is genetically modified food that improves its agronomic characteristics. Other genetically modified foods that are close to commercialisation clearly bring with them nutritional improvements. Most recent scientific data concerning the analysis of the genetically modified and conventional crop genomes (used in organic farming) convincingly show that the former are as natural, or as *artificial,* as the latter. Therefore, we understand that the scientific evidence does not justify the current rejection of genetically modified crops by organic agriculture.

We do not believe that there is a panacea to feed all mankind, now and in the future, while at the same time preserving the environment. Farmland must provide us with food and fuel, while at the same time preserving biodiversity. When it comes to looking for sustainable and just methods to produce varied and sufficient foodstuffs, we must use all the technologies that best fit in with each specific region, including biotechnology and the most advanced technologies, because the challenge we are facing is enormous[238].

From the perspective of the ethics of responsibility, we propose, as a conclusion to this study, that organic agriculture accept the use of certain genetically modified crops: insect and disease-resistant crops and those that tolerate droughts and offer nutritional improvements.

Out of respect for the organic farming philosophy of not using synthetic chemical products, we leave herbicide tolerant crops out of our proposal with one exception, because these products do have to be used for their cultivation. We propose to include herbicide tolerant maize and sorghum, both genetically modified and/or conventional, because they enable the efficient control of the harmful *Striga* in Sub-Saharan Africa, as we have described above. The importance of these basic foods undoubtedly justifies their inclusion from the perspective of responsibility towards current and future generations.

Whatever the case, we wish to highlight the fact that herbicide tolerant genetically modified crops use products that are much less aggressive for the environment than conventional herbicides, require much less of these compounds than conventional crops and enable the use of low tillage techniques to reduce the erosion of the upper soil layer. These characteristics of herbicide tolerant crops encourage the use of low intensity agronomic techniques, in line with the pillars of sustainability and respect for nature that we expressed at the beginning of this study.

In our opinion, the joining of these two ways to produce food -genetically modified seeds and organic farming- could be highly beneficial, both for current and future generations here, and in developing countries, as well as for the environment, because there are important synergies between the two.

Genetically modified crops and organic farming are not opposites, as many would have us believe, but complementary. Organic farming advocates a limited use of synthetic products. In reality, as we have seen, it does without pesticides and chemical fertilisers using crop rotation to control pests, and significantly reducing soil and aquifer pollution, which is undoubtedly organic farming’s most outstanding, environmentally positive aspect. Nevertheless, this practice along with the use of so-called "green fertilisers" instead of soluble fertilisers are the main cause of the significant fall in productivity of organic agriculture (giving rise to high prices for consumers), as we have already analysed above. Due to this lower yield, we cannot support the use of organic farming as a generalised procedure to feed the world's population, because it would force us to substantially increase the amount of cropland, thus giving rise to the destruction of habitats and animal, plant and microbial biodiversity.

The reduction of the use of pesticides allowed by certain current genetically modified crops and ones that are about to be commercialised is in line with the reasoning of organic farming philosophy. Among the crops that are already being commercialised, we have studied the reductions that come with insect resistant crops, or Bt crops, which moreover, use the same microbial protein that is authorised in organic farming. The additional benefit of these crops as compared with organic ones is the significant drop in the concentration of mycotoxins, as we have seen above. Another example of a genetically modified crop that reduces the use of pesticides, because it does not need them, is flood tolerant rice[239] which is, at present, undergoing field tests. This rice allows the farmer to flood the field and thus eliminate weeds, while at the same time not causing any damage to the rice. When the water is withdrawn, the rice has a clear advantage over other plants that might begin to grow at that moment in time.

Genetically modified insect and disease resistant crops (virus and nematode infestations) increase yield by reducing losses, without the need to use additional materials. Drought and marginal land tolerant crops that are close to commercialisation will also enable yield improvement in difficult abiotic stress conditions.

Drought tolerant crops to be commercialised in the near future doubly contribute to the sustainability of food production. On the one hand, they enable the production of at least the same amount of food in adverse conditions (which in itself already represents an increase in the yield that would be obtained from not using these seeds), and on the other hand, they reduce the amount of water that would be needed to obtain the same amount of food. Considering that due to climate change a significant reduction in the amount of available water is expected, particularly in Sub-Saharan Africa countries, these crops can be very important for their inhabitants.

In Europe and the USA, at present, the fact that organic farming yield is not as high at it could be does not represent a serious problem because there is no shortage of food and people have access to varied and nutritional diets. However, in some developing countries, yield improvement in agriculture is a very important priority as has been stated recently by Jacques Doiuf, Director of the FAO[240]. Moreover, given the foreseeable shortage of water that climate change conditions may worsen even further, above all in Africa and some European countries like Spain, the possibility of using drought tolerant crops will enable an improvement in yield in adverse conditions.

From the socio-economic point of view, acceptance of the use of genetically modified crops by organic agriculture and, ultimately, by customers would avoid the ongoing sterile confrontations between supporters of one or the other side, each of which is fighting for supremacy over the other. This acceptance would enable us to focus on finding the best solutions for the environment and for people who, in the end, need nutritional and healthy food in sufficient quantity. Moreover, it would solve the problem of the drop in competitiveness of European farmers and livestock breeders. Likewise, it would do away with the current barriers that many developing countries have imposed on themselves in order not to compromise their export market to Europe, and could give a genuine boost to their food production, mainly to the benefit of their peoples.

EPILOGUE

Perhaps this proposal may surprise, or initially even generate a certain rejection in many people who are genuinely committed to organic farming. As we have explained above, there is a deep-seated conviction that the use of genetically modified seeds would be considered as a betrayal of their principles. From a in-depth reading of those principles, however, we understand that many genetically modified seeds, available at present or in the near future, do not only not contradict the organic farming philosophy, but rather, in many cases, can contribute to greater food production sustainability. Thus have we explained herein, in detailed reference to documents and other sources of information in which those interested can check the data provided.

Experience has taught human civilisations that prejudices and staunchly inflexible stands not only hinder the sorting out of problems, but quite often, make them even worse. In the hope that together we can find a meeting ground, we wish to encourage people to read our work and to suspend for a while any pre-conceived notions they may have and take time out to study our proposal with as open a mind as possible. We would gladly receive any appraisals, comments and objections our readers might wish to make, convinced as we are that the meeting of different opinions is always an enriching experience.

The film *The Heart of Jenin* describes how a Palestinian family donates the organs of their 12-year-old son who was killed by Israeli soldiers in November 2005, thus saving the lives of 8 children, among which we find the daughter of an ultra-orthodox Jewish family[241]. At the beginning, the father of the Palestinian child is deemed to be a traitor until his community sees the film. The director of the film says that "the more people on each side that dare to break down barriers and prejudices, the closer we will get to being able to live together in peace". Even though this is clearly not the same case, we feel that finding a sustainable way to produce food for all human beings is a goal that it is worthwhile joining forces to achieve.

BIBLIOGRAPHY AND OTHER DOCUMENTARY REFERENCES

[1] FAO. 2009. "More people than ever are victims of hunger". http://www.fao.org/fileadmin/user_upload/newsroom/docs/Press%20release%20 june-en.pdf. Visited on 22/10/2009.

[2] M Palacios. 2000. "Bioética práctica para el siglo XXI". In: "Bioética 2000", M Palacios (co-ordinator). International Society of Bioethics, pg.15-26.

[3] We understand by ecosystem a dynamic entity made up of a biological community and the abiotic surroundings in which it develops. Ecosystems change in time. On the one hand, living organisms adapt to the environmental conditions in which they live, and on the other hand, the habitat itself evolves as a result of physical-chemical and geological processes, as well as the activity of the organisms that inhabit it (D. Corenblit, AM Gurnell, J Steiger, E Tabacchi. 2008. "Reciprocal adjustments between landforms and living organisms: Extended geomorphic evolutionary insights". Catena 73, 261-273).

[4] Perhaps the most remarkable case of the impact of living organisms on the ecosystem is the transition of a practically oxygen free atmosphere to an oxygenated one, a fact linked to the proliferation of photosynthesizing cyanobacteria over 2,400 million years ago (TW Lyons. 2007. "Oxygen's rise reduced". Nature 448, 1005-1006).

[5] LR Kump, ME Barley. 2007. "Increased subaerial volcanism and the rise of atmospheric oxygen 2.5 billion years ago". Nature 448, 1033-1036. This increase in oxygen brought with it the extinction of practically all living organisms extant at that time for which oxygen was highly toxic, thus favouring the appearance of aerobic organisms among which we find ourselves.

[6] A. Trewavas. 2002. Malthus foiled again and again. Nature 418, 668-670.

[7] United Nations. "The World at Six Billion". http://www.un.org/esa/population/publications/sixbillion/sixbilpart1.pdf Visited on 7/10/2009.

[8] F. García Olmedo. 2009. El ingenio y el hambre. De la revolución agrícola a la transgénica. Crítica. pg. 217.

[9] Fertilizer: History. http://en.wikipedia.org/wiki/Fertilizer#History. Visited on 22/10/2009.

[10] F García Olmedo. 2009. Op. cit., pgs. 177-191.

[11] MJ Chrispeels, DE Sadava. 2004. Plants, Genes and Agriculture. Jones and Bartlett Publishers, Boston, pp.

[12] RE Green, SJ Cornell, JPW Scharlemann, A Balmford. 2005. "Farming and the fate of wild nature". Science 307, 550-555.

[13] D Tilman, KG Cassman, PA Matson, R Naylor, S Polasky. 2002. Agricultural sustainability and intensive production practices. Nature 418, 671-677.

[14] A Lecaros. 2008. "Las éticas de la tierra: por qué estamos obligados a responder moralmente a la Tierra". Bioètica & Debat 14, 15-18.

[15] M Palacios. 2000. Op. cit.

[16] Comité Asesor de Ética en la Investigación Científica y Técnica. 2004. Informe – Organismos modificados genéticamente en la agricultura y la alimentación. Fundación Española de Ciencia y Tecnología.

[17] E Muñoz. 2002. Biotecnología y Sociedad – Encuentros y Desencuentros. Cambridge University Press. pg. 114.

[18] P Taylor. 1986. "Respect for nature – a theory of environmental ethics". Princeton University Press.

[19] J Masiá. 2005. "Ecología y eco-ética". In: Tertulias de Bioética. Editorial Sal Terrae, pg. 171.

[20] Comité Asesor de Ética en la Investigación Científica y Técnica. 2004. Op. cit.

[21] J Masiá. 2005. Op. cit., pg. 170.

[22] FAO. 2003-2004. El estado mundial de la Agricultura y la Alimentación. La Biotecnología Agrícola: ¿una respuesta a las necesidades de los pobres?. http://www.fao.org/docrep/006/Y5160s/Y5160s00.HTM Visited on 10/10/2009.

[23] Objetivos del Milenio: Web page: http://www.un.org/spanish/millenniumgoals. Visited on 22/10/2009.

[24] The Spanish translation of the English terms safety and security is ambiguous because they are nearly always translated by the same word "seguridad". In this paper we will occasionally use "inocuidad" (harmless) to refer to safety, that is to say the absence of any negative effect on consumers' health, and "accesibilidad" (availability) to refer to security, thus indicating the availability of food in the sufficient amount and quality for all.

[25] G Brundtland (ed). 1987. Our Common Future: The World Commission on Environment and Development. Oxford University Press.

[26] DL Meadows, DH Meadows, J Randers, & WW BehrensIII. Original title The Limits to Growth, New York 1972, published in Spanish as Los límites del crecimiento. Informe del Club de Roma sobre el Predicamento de la Humanidad, Fondo de Cultura Económica, México, 1972, in which the first three authors insisted twenty years afterwards Más allá de los límites del crecimiento, edition in Spanish in El País-Aguilar, 1992.

[27] FAO. 2004. The state of food insecurity in the world. Monitoring progress towards the World Food Summit and Millennium Development Goals. FAO (ISBN: 92-5-1051X). http://www.fao.org/docrep/007/y5650e/y5650e00.htm Visited on 22/10/2009.

[28] J Labrador. 2002. "Aproximación a las bases técnicas de la agricultura ecológica". In: Manual de Agricultura y Ganadería Ecológica (J. Labrador, J: Porcuna y A.

Bello, eds). Sociedad Española de Agricultura Ecológica y EUMEDIA, pgs. 17-26.

[29] FAO. 2005. The state of food insecurity in the world. Eradicating world hunger – key to achieving the Millennium Development Goals. FAO (ISBN: 92-5-105384-7). http://www.fao.org/docrep/008/a0200e/a0200e00.htm Visited on 22/10/2009.

[30] CC de Lauwere. 2009. "Agricultural entrepreneurship and sustainability – is it a good or bad fit?". In: Ethical futures: bioscience and food horizons (K Millar, PH West & B Nerlich, eds). Wageningen Academic Publishers, pp. 211 – 216.

[31] W Aiken. 1998. "The goals of agriculture and weed science". Weed Science 46(6), 640-641.

[32] A Clonan, M Holdsworth, J Swift & P Wilson. 2009. "Awareness and attitudes of consumers to sustainable food", In: Ethical futures: bioscience and food horizons. Op. cit., pp. 205 – 210.

[33] Web page: http://www.ias.csic.es/presentacion.htm. Visited on 6 June 2009.

[34] The Keystone Center. 2009. Field to market: the Keystone Alliance for Sustainable Agriculture. First report: January 2009.
http://www.keystone.org/spp/environment/sustainability/field-to-market
Even though, in principle, this publication has not yet undergone a peer review as do other articles in scientific journals, Appendix B of the report brings together 17 external expert opinions from universities, government agencies and companies that deal in farming sustainability issues.

[35] JL Porcuna. 2003. "La sanidad de los cultivos agrícolas. El punto de vista agroecológico". In: Fundamentos de Agricultura Ecológica. (J de las Heras, C Fabeiro & R Meco, eds). Ediciones de la Universidad de Castilla-La Mancha, pgs.155-174.

[36] IM Goklany. 2001. The Precautionary Principle. A critical appraisal of environmental risk assessment. Cato Institute, Washington, pg. 29-56.

[37] Web page of Bayer Crop Science:
http://www.bayercropscience.es/BCSWeb/WWW/BCS_ES_Internet.nsf/id/ES_AC_Generalidades. Visited on 27/09/2009.

[38] E Muñoz. 2002. Biotecnología y sociedad. Encuentros y desencuentros. Cambridge University Press. pg. 126.

[39] Nuffield Council on Bioethics. 2004. The use of genetically modified crops in developing countries – a follow-up discussion paper. Latimer Trend & Co., pg. 47, paragraph 4.2.
http://www.nuffieldbioethics.org/go/ourwork/gmcrops/publication_313.html Visited on 22/10/2009.

[40] United Nations. 2001. Human Development Report 2001. Making New Technologies Work For Human Development. pg. 77.
http://hdr.undp.org/en/media/HDR_2001_ES.pdf Visited on 22/10/2009.

41 J Diouf. 2009. La agricultura hacia 2050: los retos a superar. http://www.fao.org/news/story/es/item/36195/icode Visited on 12/10/2009.

42 The Royal Society. 2009. Reaping the benefits: science and the sustainable intensification of global agriculture. http://royalsociety.org/displaypagedoc.asp?id=35510. Visited on 22/10/2009.

43 F García Olmedo. 2009. Op. cit. Pg. 168.

44 The development of analytical techniques that make it possible to quantify the amount of compounds up to micrograms per kilo (parts per trillion, or ppt) have contributed to the perception of many people who feel that everything is contaminated with chemical products.

45 She was already well known before the publication of Silent Spring for her books addressed to the general public on scientific matters concerning the sea, Under the sea-wind (1941), The Sea around us (1951; National Book Award in 1952) and The edge of the sea (1955).

46 SA Briggs. 1987. "Rachel Carson: her vision and her legacy". In: Silent Spring Revisited. GJ Marco, RM Hollingworth, W Durham (eds.), American Chemical Society, Washington DC, pgs 3-11.

47 DDT is currently authorised in about twenty countries around the world in which malaria is a serious public health problem to control the mosquito that spreads the disease. The World Health Organisation recommends the fumigation of house interiors (http://www.who.int/ipcs/capacity_building/who_statement.pdf). Also quoted by F. García Olmedo in Ingenio y el hambre, pg. 218.

48 BN Ames, M Profet, LS Gold. 1990. "Dietary pesticides (99.99% all natural)". Proceedings of the National Academy of Sciences USA 87, 7777-7781.
BN Ames, M Profet, LS Gold. 1990. "Nature's chemicals and synthetic chemicals: comparative toxicology". Proceedings of the National Academy of Sciences USA 87, 7782-7786.

49 Glossary of agriculture-related terms. http://ucce.ucdavis.edu/files/filelibrary/1068/8286.pdf Visited on 12/10/2009.

50 EC Regulation 834/2007 of 28 June 2007 on organic production and labelling of organic products. Official Journal of the European Union L187, pg. 1-22, 20 of July 2007. http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:189:0001:0023:ES:PDF Visited on 6/06/2009.

51 Web page of the National Organic Program: http://www.usda.gov/wps/portal/!ut/p/_s.7_0_A/7_0_1OB?navid=ORGANIC_CERTIFICATIO&navtye=RT&parentnav=AGRICULTURE Visited on 12/10/2009.

52 See FAO documents:
http://www.fao.org/ag/ca/la.html; Conservation agriculture - Conserving resources above -and below- the ground: ftp://ftp.fao.org/docrep/fao/010/ai552e/ai552e00.pdf; Conservation Agriculture - Matching production with sustainability: ftp://ftp.fao.org/agl/agll/ch10/ch104.pdf Visited on 12/10/2009.

[53] MA Altieri. 1999. Agroecología – bases científicas para una agricultura sustentable. Nordan-Comunidad, Montevideo, pg. 88.

[54] MA Molina, J Perez. 2004. "La agricultura ecológica en España". In: Agricultura Ecológica y Alimentación. Análisis y funcionamiento de la cadena comercial de productos ecológicos. J Briz (coordinador). Fundación Alfonso Martín Escudero, Madrid. pg. 7 - 72.

[55] EC Regulation 834/2007 of 28 June 2007, Op. cit.

[56] Statements from the web page: http://www.fao.org/news/story/es/item/29402/icode Visited on 12/10/2009.

[57] J Labrador, 2002. "Aproximación a las bases técnicas de la agricultura ecológica". In: Manual de Agricultura y Ganadería Ecológica. J Labrador, JL Porcuna, A Bello, editores. Eumedia, pgs. 17-35.

MA Altieri. 1999. Op. cit., pgs. 262-280.

[58] GJ Brewer. 2008. "The risks of free copper in the body and the development of useful anticopper drugs". Current Opinion in Clinical Nutrition and Metabolic Care 11(6), 727-732.

[59] Labrador, 2002. Op. cit., pgs. 291-304.

[60] A Trewavas. 2004. A critical assessment of organic farming-and-food assertions with particular respect to the UK and the potential environmental benefits of no-till agriculture. Crop Protection 23(9), 757-781.

[61] FAO. 2007. Conferencia internacional sobre agricultura orgánica y seguridad alimentaria. ftp://ftp.fao.org/docrep/fao/meeting/012/J9918S.pdf Visited on 27/10/2009.

[62] PC Ronald, RW Adamchack. 2008. Tomorrow's Table: organic farming, genetics and the future of food. Oxford University Press, pg. 24. The original article, "Food Inc. swallows organics", can be found In:
http://www.canada.com/edmontonjournal/news/story.html?id=15471e4c-6c19-452d-af5e-750d61a01888. Visited on 10/10/2009.

[63] R Paarlberg. 2008. Starved for Science: how biotechnology is being kept out of Africa. Harvard University Press, pg. 102-103.

[64] Food Navigator. 2009. Soil Association backs down on organic air freight issue. http://www.foodnavigator.com/content/view/print/234283. Visited on 10/10/2009.

[65] R Paarlberg. 2008. Op. cit., pg. 103.

[66] Available on the web page:
http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:250:0001:0084:ES:PDF Visited on 12/10/2009.

[67] Council Regulation (EEC) 2092/91 of 24 June 1991, on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs.

[68] Web page: http://www.nal.usda.gov/afsic/pubs/ofp/ofp.shtml Visited on 12/10/2009.

[69] Web page: http://www.fao.org/news/story/en/item/7502/icode Visited on 12/10/2009.

70 The *FAO warns of the need for a change in agriculture in order to be able to feed the planet:* http://www.fundacion-antama.org/noticia/la-fao-advierte-la-necesidad-de-un-cambio-en-la-agricultura-para-poder-alimentar-al-planeta Visited on 12/10/2009.

71 B Liebhardt. 2001. "Get the facts right: organic agriculture yields are good". *Information Bulletin*. Organic Farming Research Foundation 10: 1, 4-5.

72 RF Denison, D Bryant, TE Kearney. 2004. "Crops yields over the first nine years of LTRAS, a long term comparison of field crop systems in a Mediterranean climate". *Field Crops Research* 86: 267-277.

73 C Badgley, J Moghtader, E Quintero, E Zakem, MH Chappll, K Avilés-Vázquez, A Samulon, I Perfecto. 2007. "Organic Agriculture and the global food supply". *Renewable Agriculture and Food Systems* 22, 86-108.

74 KWT Goulding, A Trewavas. 2009. "Can organic agriculture feed the world?". AgBioWorld http://www.agbioworld.org/newsletter_wm/index.php?caseid=archive&newsid=2894. Visited on 24/06/2009.

75 JL Kitchen, GK McDonald, KW Shepherd, MF Lorimer, RD Graham. 2003. "Comparing wheat grown in South Australian Organic and Conventional wheat farming systems. I. Growth and grain yield". *Australian Journal of Agricultural Research* 54, 889-901.

76 P Mäder, A Fliessbach, D Dubois, L Gunst, P Fried, U Niggli. 2002. "Soil fertility and biodiversity in organic farming". Science 296, 1694-1697.

77 A Trewavas. 2004. Op. cit.

78 "Organic FAQs". Nature 428, 796-798.

79 C. Lacasta. 2003. "Alternativas al uso de herbicidas". In: Fundamentos de agricultura ecológica (J de las Heras, C Fabeiro, & R Meco, eds), Servicio de publicaciones de la Universidad de Castilla-La Mancha, pg. 175 – 192.

80 J Diouf, 2009. La agricultura hacia 2050: los retos a superar. http://www.fao.org/news/story/es/item/36195/icode Visited on 12/10/2009.

81 L Escajedo San Epifanio. 2008. "Biotechnologie, Santé et Environnement dans L'union Européenne: Aspects Politiques et Juridiques". *Revue du Marché commun et de l'Union européenne,* n°517, avril 2008, pp 255-266.

82 Article 12 of Regulation (EC) No 1829/2003 of the European Parliament and Council, 22 September 2003 on genetically modified food and feed. Accessible at: http://eur-lex.europa.eu/pri/es/oj/dat/2003/l_268/l_26820031018es00010023.pdf Visited on 26/10/2009.

83 This technique is also used in certain paternity tests, in forensic analysis to identify those suspected of committing a crime, in food analysis to identify animal and plant species (e.g.: peppers stuffed with cod), and in a lot of other applications.

84 FE Ahmed. 2002. "Detection of genetically modified organisms in foods". Trends in Biotechnology 20(5), 215-223.

85 KH Engel, F Moreano, A Ehlert, U Busch. 2006. "Quantification of DNA from genetically modified organisms in composite and processed foods". Trends in Food Science and Technology 17, 490-497.

85 Offical Gazette of the Spanish Sate, 19 July 1986.

86 Web page of the National Organic Program of the American Department of the Agriculture contains the regulations to be applied in the USA to produce organic foodstuffs. http://www.ams.usda.gov/AMSv1.0/nop Visited on 10/10/2009.

87 P Roland, B Fouche. 2006. "Genetic engineering and organic production systems". Publicación 8188 de la University of California, Division of Agriculture and Natural Resources (series of publications with external assessors).

International Federation of Organic Agricultural Movements, *The Principles of Organic Agriculture*. http://www.ifoam.org/about_ifoam/principles/index.html. Visited on 28/06/2009.

89 Spanish Society of Biotechnology. 2007. Plantas Transgénicas. Publication available at: http://www.sebiot.org. Visited 2/09/2009.

90 This is a similar situation to that of an Intel processor that the majority of computers carry, regardless of the brand; or that of a CD player that has been adapted to different car makes; or to any electrical device that has been bought in the United Kingdom the plug of which needs to be changed so that it can work in Spain.

91 D Charles. 2001. *The Lords of the Harvest. Biotec, big money and the future of food*. Perseus Publishing, Cambridge (Mass. USA). This book tells the story of the first years in the development of genetically modified crops.

92 P Zambryski, H Joos, C Genetello, J Leemans, M Van Montagu, J Schell. 1983. "Ti plasmid vector for the introduction of DNA into Plant Cells without alteration of their normal regeneration capacity". *EMBO Journal* 2(12), 2143-2150.

93 KA Barton, AN Binns, AJ Matze, MD Chilton. 1983. "Regeneration of intact tobacco plants containing full length copies of genetically engineered T-DNA and, transmission of T-DNA to R1 progeny". Cell 32(4), 1033-1043.

94 RT Fraley, SG Rogers, RB Horsch, PR Sanders, JS Flick, SP Adams, ML Bittner, LA Brand, CL Fink, JS Fry, GR Galluppi, SB Goldberg, NL Hoffmann, SC Woo. 1983. "Expression of bacterial genes in plant cells". *Proceedings of the National Academy of Sciences USA* 80, 4803-4807.

95 C James. Global review of Commercialized genetically modified crops, 1999. Informe 12-1999.

96 C James. 2009. "Situación mundial de la comercialización de cultivos biotecnológicos/transgénicos en 2008". Brief 39. http://www.isaaa.org. Visited on 38/06/2009.

97 Genetic Engineering vs. Traditional Breeding Timeline. Animación interactiva. http://croptechnology.unl.edu/download.cgi. Visited on 26/10/2009.

98 A Slater, N Scott, M Fowler. 2008. *Plant Biotechnology: the genetic manipulation of plants* (2nd edition). Oxford University Press.

99 A Slater, NW Scott, MR Fowler. 2008. Op. cit., Chapter 6. There are also other strains of this bacterium that produce toxic proteins for beetles (such as the potato beetle) or diptera (such as the mosquito).

100 Web page: http://extoxnet.orst.edu/pips/bacillus.htm Visited on 22/10/2009.

101 Metabolic pathways are a series of chemical reactions by which a specific compound is transformed into another compound required for the correct functioning of a cell. For example, dietary glucose can be transformed into glycogen, or into lipids, or into a variety of different compounds. Each one of these reactions is catalysed by an enzyme which is a protein capable of bringing about this reaction.

102 A Slater, NW Scott, MR Fowler. 2008. Op. cit., pg. 105-132.

103 A Slater, NW Scott, MR Fowler. 2008. Op. cit., pg. 105-132.

104 MJ Shipitalo, RW Malone, LB Owens. 2008. "Impact of glyphosate-tolerant soybean and glufosinate-tolerant corn production on herbicide losses in surface runoff". *Journal of Environmental Quality* 37, 401-408.

105 MR Tuinstra, S Soumana, K Al-Khatib, I Kapran, A Toure, A van Ast, L Bastiaans, NW Ochanda, I Salami, S Dembele. 2009. "Efficacy of herbicide seed treatments for controlling Striga infestations of sorghum". Crop Science 49, 923-929.

106 C Gonsalves, DR Lee, D Golsaves. 2004. "Genetically modified virus-resistant papaya: the Hawaiian "Rainbow" was rapidly adopted by farmers and is of major importance in Hawaii today". American Plant Society http://www.apsnet.org/online/feature/rainbow/papaya.pdf. Visited on 22/10/2009.

107 International Food Policy Research Institute. 2009. "Climate change. Impact on agriculture and costs of adaptation". http://www.ifpri.org/sites/default/files/publications/pr21.pdf Visited on 28/09/2009.

108 National. Center for Atmospheric Research.:
http://www.ucar.edu/news/releases/2005/drought_research.shtml

109 See document at FAO web site:
ftp://ftp.fao.org/agl/aglw/docs/factsheet_wwf_spa.pdf Visited on 22/10/2009.

110 GO Edmeades. 2008. *Drought tolerance in maize: an emerging reality*. http://www.isaaa.org

111 JM de la Fuente, V Ramirez-Rodriguez, JL Cabrera-Ponce, L Herrera-Estrella. 1997. "Aluminum tolerance in genetically modified plants by alteration of citrate synthesis". Science 276, 1566-1568.
J Lopez-Bucio, O Martinez de la Vega, A Guervara-Garcia, L Herrera-Estrella. 2000. "Enhanced phosphorus uptake in genetically modified tobacco plants that overproduce citrate". *Nature Biotechnology* 18(4), 450-453.

112 P Christou, RM Twyman. 2004. "The potential of genetically enhanced plants to address food insecurity". *Nutrition Research Reviews* 17, 23-42.

113 B Grant. 2009. "Where is the super food?". The Scientist, sept. 2009, pg. 31- 37.

114 HE Bouis, BM Chassy, JO Ochanda. 2003. "Genetically modified food crops and their contribution to human nutrition and food quality". *Trends in Food Science and Technology* 14, 191-209.

115 Note by the Canadian Food Inspection Agency authorising maize with a high lysine content: http://www.inspection.gc.ca/english/plaveg/bio/dd/dd0661e.shtml. Visited on 22/10/2009.

Note by Monsanto describing US Department of Culture authorisation of maize with a high lysine content:
http://monsanto.mediaroom.com/index.php?s=43&item=69&printable Visited on 22/10/2009.

116 Fundación Antama: http://www.fundacion-antama.org/noticia/canad-aprueba-un-nuevo-tipo-de-soja-genetically modifieda Visited on 22/10/2009.

117 AJ Kinney, S Knowlton. 1998. "Designer oils: the high oleic acid soybean". In: *Genetic modification in the food industry. A strategy for food quality improvement*". S Roller, S Harlander (eds.). Blackie Academic & Professional. London, pg.s 193-211.

118 C Zhu, S Naqvi, S Gomez-Calera, AM Pleacho, T Capell, P Christou. 2007. "Genetically modified strategies for the nutritional enhancement of plants". Trends in Plant Science 12(12), 548-555.

119 Data quoted on the "Golden Rice" web page: http://www.goldenrice.org Visited on 5/09/2009.

120 JA Paine, CA Shipton, S Chaggar, RM Howells, MJ Kennedy, G Vernon, SY Wright, E Hinchiffle, JL Adams, AL Silverstone, R Drake. 2005. "Improving the nutritional value of Golden Rice through increased pro-vitamin A content". *Nature Biotechnology* 23, 482-487.

121 G Tang, J Qin, GG Dolnikowski, RM Russell, & MA Grusak. 2009. "Golden Rice is an effective source of vitamin A". *American Journal of Clinical Nutrition*. 15 de abril, d.o.i: 10.3945/ajcn.2008.27119.

122 I Potrykus. 2001. "Golden Rice and beyond". *Plant Physiology* 125, 1157-1161.

123 S Naqvi, C Zhu, G Farre, K Ramessar, L Bassie, J Breitenbach, D Pérez-Conesa, G Ros, G Sandmann, T Capell, P Christou. 2009. "Genetically modified multivitamin corn through biofortification of endosperm with three vitamins representing three distinct metabolic pathways". *Proceedings of the National Academy of Sciences USA* 106, 7762-7767.

124 S Ufaz, C Galili. 2008. "Improving the content of essential amino acids in crop plants". *Plant Physiology* 147, 954-961.

125 E Butelli, L Titta, M Giorgio, HP Mock, A Matros, S Peterek, EGWM Schijlen, RD Hall, AG Bovy, J Luo, C Martin. 2008. "Enrichment of tomato fruits with health-promoting anthocyanins by expression of select transcription factors". *Nature Biotechnology,* 26, 1301-1308.

126 HG Damude, AJ Kimney. 2008. "Enhancing plant seed oils for human nutrition". *Plant Physiology* 147, 962-968.

127 Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified orga-

nisms. Available at
http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2001:106:0001:0038:ES:PDF Visited on 26/10/2009.

[128] EFSA. 2006. *Guidance document of the scientific panel on Genetically Modified Organisms for the Risk Assessment of Genetically Modified Plants and Derived Food and Feed*. And its 2008 update. http://www.efsa.europa.eu/EFSA/efsa_locale-1178620753812_1178620775747.htm. For stacked genes: Guidance document for the risk assessment of genetically modified plants containing stacked transformation events by the Scientific Panel on Genetically Modified Organisms (mayo 2007). http://www.efsa.europa.eu/EFSA/efsa_locale1178620753812_1178623591786.htm.

[129] European Group on Ethics. 2008. Report can be found at http://ec.europa.eu/european_group_ethics/docs/agriculture_technologies_ethics.pdf Visited on 22/10/2009.

[130] World Health Organisation. 2002. "20 questions on genetically modified foods". http://www.who.int/foodsafety/publications/biotech/en/20questions_es.pdf Visited on 4/10/2009.

[131] Joint declaration of the Academy of Sciences of Brazil, the Academy of Sciences of China, the Academy of Sciences of India, the Academy of Sciences of México, the Academy of Sciences of the USA, the UK Royal Society and the *Academy of Sciences of the Third World. 200. Genetically modified Plants and World Agriculture*. Accesible en http://www.nap.edu/catalog.php?record_id=9889 Visited on 27/10/2009.

[132] FAO Declaration on biotechnology. 2000. Available at: http://www.fao.org/biotech/stat.asp?lang=es Visited on 27/10/2009.

[133] British Medical Association. 2004. "Genetically modified foods and health: a second interim statement". http://www.bma.org.uk/images/GM_tcm41-20804.pdf Visited on 4/10/2009.

[134] Union of the German Academies of Science and Humanities. 2006. "Are there health hazards for the consumers from eating genetically modified foods?. http://www.akademienunion.de/_files/memorandum_gentechnik/GMGeneFood.pdf Visited on 4/10/2009.

[135] GM Science Review: An open Review of the science relevant to GM crops and food based on the interest and concern of the public. The Royal Society (London) First Report July 2003, Second Report January 2004.
http://www.gmsciencedebate.org.uk/report/pdf/gmsci-report2-pt1.pdf Visited on 4/10/2009.

[136] Society of Toxicology Position Paper. 2002. "The safety of genetically modified foods produced through biotechnology".
http://www.toxicology.org/ai/gm/GM_Food.asp Visited on 4/10/2009.

[137] BM Chassy. 2002. "Food safety evaluation of crops produced through biotechnoloy". *Journal of the American College of Nutrition,* 21, 166S-173S.

[138] Informe BEETLE Report. *Long-term effects of genetically modified (GM) crops on health and the environment (including biodiversity): prioritisation of potential risks and delimitation of uncertainties*. Mayo 2009. http://ec.europa.eu/environment/biotechnology/pdf/beetle-report.pdf. Visited on 29/07/2009.

[139] EFSA. 2009. Consolidated presentation of the joint Scientific Opinion of the GMO and BIOHAZ Panels on the "Use of Antibiotic Resistance Genes as Marker Genes in Genetically Modified Plants" and the Scientific Opinion of the GMO Panel on "Consequences of the Opinion on the Use of Antibiotic Resistance Genes as Marker Genes in Genetically Modified Plants on Previous EFSA Assessments of Individual GM Plants". Question number: EFSA-Q-2009-00589, EFSA-Q-2009-00593, EFSA-Q-2008-411, EFSA-Q-2008-04977. http://www.efsa.europa.eu/EFSA/efsa_locale-1178620753812_1211902604575.htm Visited on 4/10/2009.

[140] RA Etzel. 2002. "Mycotoxins". *Journal of the American Medical Association* 287(4), 425-427.

[141] GP Munkvold, RL Hellmich, LG Rice. 1999. "Comparison of fumonisin concentrations in kernels of genetically modified Bt maize hybrids and nongenetically modified hybrids". Plant Disease 83(2), 130-138.

BG Hammond, KW Campbell, CD Pilcher, TA Degooyer, AE Robinson, BL McMillen, SM Spangler, SG Riordan, LG Rice, JL Richard. 2004. "Lower fumonisin mycotoxin levels in the grain of Bt corn grown in the United States in 2000-2002". *Journal of Agricultural and Food Chemistry* 52(5), 1390-1397.

[142] B Bakan, D Melcion, D Richard-Molard, B Cahagnier. 2002. "Fungal growth and *Fusarium* mycotoxin content in isogenic traditional maize and genetically modified maize grown in France and Spain". *Journal of Agricultural and Food Chemistry* 50, 728-731.

[143] Commission Regulation (EC) No 1126/2007 of 28 September 2007 amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs as regards Fusarium toxins in maize and maize products. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:255:0014:0014:ES:PDF Visited on 22/10/2009.

[144] Rapid Alert System for Food and Feed:
http://ec.europa.eu/food/food/rapidalert/index_en.htm Visited on 26/10/2009.

[145] Fundación Antama. http://www.fundacion-antama.org/noticia/cinco-os-sin-alertas-por-micotoxinas-en-el-ma-z-transg-nico. Visited on 28/09/2009.

[146] F Wu. 2007. "Bt corn and impact on mycotoxins". *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources* 60 (2), 8 pg.

[147] FAO. 2004. *Los trabajadores agrícolas necesitan más protección contra los plaguicidas*. http://www.fao.org/newsroom/es/news/2004/50709/index.html. Visited on 19/10/2009.

[148] J Huang, R Hu, S Rozelle, C Pray. 2005. "Insect resistant GM rice in farmers' fields: assessing productivity and health effects in China". Science 308, 688-690.

149 Asociación Española de Agricultura de Conservación: http://www.aeac-sv.org/html/intro.html. Visited on 22/10/2009.

150 S Sankula, G Marmon, E Blumenthal. 2005. *Biotechnology-derived crops planted in 2004 – Impacts on US Agriculture*. National Center for Food and Agricultural Policy. http://www.whybiotech.com/resources/tps/BiotechnologyDerivedCropsPlantedin2004.pdf Visited on 19/10/2009.

151 European Group on Ethics in Science and New Technologies to the European Commission. 2008. "Ethics of modern developments in agriculture technologies. Opinion No. 24". http://ec.europa.eu/european_group_ethics/docs/agriculture_technologies_ethics.pdf Visited on 22/10/2009.

152 MJ Shipitalo, RW Malone, LB Owens. 2008. Op. cit.

153 RF Service. 2007. "A growing threat down on the farm". *Nature* 316, 1114-1117.

154 JH Benedict. 2003. "Strategies for controlling insect, mite, and nematode pests". In: *Plants, Genes and Crop Biotechnology*. Op. cit., pgs. 414-445.

155 D Gurian-Sherman. 2009. Failure to Yield: evaluating the performance of genetically engineered crops. Study commissioned by the Union of Concerned Scientists. April 2009.
http://www.ucsusa.org/food_and_agriculture/science_and_impacts/science/failure-to-yield.html Visited on 22/10/2009.

156 JH Benedict. 2003. Op. cit.

157 D Gurian-Sherman. 2009. Op. cit.

158 S Sankula, G Marmon, E Blumenthal. 2005. Op. cit.

159 J Huang y cols. 2005. Op. cit.

160 FAO. 2004. *El estado mundial de la agricultura y la alimentación*. Op. cit., pg. 54.

161 JH Benedict. 2003. Op. cit.

162 KM Wu, YH Lu, HQ Feng, YY Jiang, JZ Zhao. 2008. "Suppression of cotton bollworm in multiple crops in China in areas with Bt toxin-containing cotton". Science 321, 1676-1678.

163 HJ Atkinson, J Green, S Cowgill, A Levesley. 2001. "The case for genetically modified crops with a poverty focus". *Trends in Biotechnology* 19(3), 91-96.

164 MJ Chrispeels, DE Sadava. 2003. Op. cit.

165 The development of the genetically modified, virus-resistant papaya is described on the American Phytopathological Society web site: http://www.apsnet.org/education/feature/papaya. Visited on 11/10/2009.

166 C James. 2009. Op. cit.

167 T Raney, P Pingali. 2007. "Agricultura transgénica". *Investigación y Ciencia,* November 2007, 60-67.

168 M Gómez-Barbero, J Berbel, E Rodríguez-Cerezo. 2008. "Bt corn in Spain – the performance of the EU's first GM crop". *Nature Biotechnology* 26(4), 384-386.

169 A Bravo, M Soberón. 2008. "How to cope with insect resistance to Bt toxins". *Trends in Biotechnology*. 26, 573-579.

170 DEFRA Farm Scale Evaluations: http://www.defra.gov.uk/environment/quality/gm/crops/fse.htm Visited on 16/10/2009. Access can be had from this web page to the corresponding scientific publications as well.

171 JE Losey, LS Rayor, M Carter. 1999. "Genetically modified pollen harms monarch larvae". Nature 399, 214.

172 The US Department of Agriculture web site: http://www.ars.usda.gov/is/br/btcorn contains the relevant scientific publications, as well as a great amount of information on this case.

173 M Marvier, C McCreedy, J Regetz, &P Kareiva. 2007. "A meta-analysis of effects of Bt cotton and maize on non-target invertebrates". *Science* 316, 1475-1477.

174 MJ Crawley, SL Brown, RS Hails, DD Kohn, & M Rees. 2001. "Genetically modified crops in natural habitats". *Nature* 409, 682-683.

175 WJ Belasco. 2007. *Appetite for change: how the counterculture took on the food industry*. Cornell University Press, pg. 220 – 221.

176 F García Olmedo. 2009. Op. cit., pg. 221.

177 K Ammann. 2008. "Integrated farming: why organic farmers should use genetically modified crops". *New Biotechnology* 25, 101-106.

178 JM Baker, ND Hawkings, JL Ward, A Lovegrove, JA Napier, MH Beale. 2006. "A metabolomic study of substantial equivalence of field-grown genetically modified wheat". *Plant Biotechnology Journal* 4, 381-392; MM Baudo, R Lyons, S Powers, GM Pastori, KJ Edwards, MJ Holdsworth, PR Shewry. 2006. "Transgenesis has less impact on the transcriptome of wheat grain than conventional breeding". Plant Biotechnology Journal 4, 369-380; R Batista, N Saibo, T Lourenço, MM Oliveira. 2008. "Microarray analysis reveal that plant mutagenesis may induce more transcriptomic changes than transgene insertion". *Proc. Nat. Acad.* Sci. USA 105, 3640-3645.g

179 Ultraviolet sun radiation is one of the causes that give rise to spontaneous mutations. As is well known, this radiation is the normal cause of the transformation of a healthy skin cell into a cancerous one, thus giving rise to a melanoma. Spontaneous mutations play a central role in the evolution of the species.

180 BS Ahloowalia, M Maluszynski, K Nichterlein. 2004. "Review: Global impact of mutation-derived varieties". Euphytica 135, 187-204.

181 Enter "Shijian-8" in Google. NY Times article of 14th April 1990, "Space seeds no threat, NASA says" de John Noble Wilford.
http://www.nytimes.com/1990/04/14/us/space-seeds-no-threat-nasa-says.html; China makes progress in space seed breeding:
http://english.peopledaily.comcn/200510/16/eng20051016_214639.html

[182] PJ Larkin, WR Scowcroft. 1981. "Somaclonal variation: a novel source of variability from cell culture for plant improvement". *Theoretical and Applied Genetics*. 60, 197-214.

[183] M Lotfi, AR Alan, MJ Henning, MM Jahn, ED Earle. 2003. "Production of haploid and doubled haploid plants of melon (Cucumis melo L.) for use in breeding for multiple virus resistance". *Plant Cell Reports* 21, 1121-1128.

[184] K Ammann. 2008. Op. cit.

[185] LJ Stadler. 1928. "Mutations in barley induced by X-rays and radium". *Science* 68, 186-187.

[186] AM van Harten. 1998. *Mutation Breeding: theory and practical applications*. Hardcove Publishers, pgs: 1-39.

[187] Joint FAO/IAEA Program: http://www-naweb.iaea.org/nafa/about-nafa/index.html. Visited on 25/06/2009.

[188] BS Ahloowalia, M Maluszynski, K Nichterlein. 2004. Op. cit.

[189] N Fedoroff, NM Brown. 2004. *Mendel in the kitchen*. Joseph Henry Press, Washington, pg. 18-19.

[190] N Fedoroff, NM Brown. 2004. Op. cit., pg. 16.

[191] El Mundo Digital (Spanish daily newspaper, on-line edition) of 30th July 2009. http://www.elmundo.es/elmundosalud/2009/07/29/nutricion/1248888711.html.

[192] RV Akeley, WR Mills, CE Cummingham, J Watts. 1968. "Lenape: a new potato variety high in solids and chipping quality". *American Potato Journal* 45, 142-145.

[193] N Fedoroff, NM Brown. 2004. Op. cit., pg. 171-172.

[194] A Zitnak, GR Johnston. 1970. "Glycoalkaloid content of B5141-6 potatoes". *American Potato Journal,* 47, 256-260.

[195] N Fedoroff, NM Brown. 2004. Op. cit., pg. 171-172.

[196] KS Rymal, OL Chambliss, MD Bond, DA Smith. 1984. "Squash containing toxic cucurbitacin compounds occurring in California and Alabama". *Journal of food Protection* 47(4), 270-271.

[197] PJ Seligman, CGT Mathias, MA O'Malley, RC Beier, LJ Fehrs, WS Serrill, WE Halperin. 1987. "Phytophotodermatitis from celery among grocery store workers". *Archives of Dermatology* 123, 1478-1482.

[198] EFSA. 2009. *2007 Annual report on pesticide residues according to Article 32 of Regulation (EC) no*. 396/2005. EFSA Scientific Report 305, 1-106. http://www.efsa.europa.eu/cs/BlobServer/Report/EFSA_2007_Annual_Report_Pesticide%20Residue_en,0.pdf?ssbinary=true. Visited on 30/07/2009.

[199] EFSA. 2009. Scientific Report 305, 1-106. Op. cit., pg. 29. The Annexes thereto are to be had at the following web site: http://www.efsa.europa.eu/EFSA/efsa_locale-1178620753812_12119026677778.htm Visited on 30/06/2009.

[200] The United Kingdom Food Standards Agency: http://www.food.gov.uk/news/newsarchive/2009/aug/letter Visited on 18/08/2009.

[201] F Magkos, F Arvaniti, A Zampelas. 2006. " Organic food: buying more safety or just peace of mind?. A critical review of the literature". *Critical Reviews in Food Science and Nutrition* 46, 23-56.

[202] MD Raigón. 2007. *Alimentos ecológicos, calidad y salud*. Ediciones de la Junta de Andalucía, Consejería de Agricultura y Pesca, pg. 15.

[203] F. Magkos, F. Arvaniti, A. Zampelas. 2006. Op. cit.

[204] The UK Food Standards Agency. The report is available at the following web site: http://www.food.gov.uk/healthiereating, entering into "Organic review published". Visited on 30/07/2009.
AD Dangour, SK Dodhia, A Hayter, E Allen, K Lock, R Uauy. 2009. "Nutritional quality of organic foods: a systematic review". *American Journal of Clinical Nutrition* 90, 680-685.

[205] As we have pointed out, low intensity conventional farming pursues the same agronomic practices as used in organic farming, without being "certified organic farming". Mixed or integrated farming results were not included in the FSA study.

[206] Food Standards Agency. Julio 2009. Comparison of composition *(nutrients and other substances)* of organically and conventionally produced foodstuffs: a systematic review of the available literature".
http://www.food.gov.uk/multimedia/pdfs/organicreviewappendices.pdf Visited on 18/08/2009.

[207] Letter from the Executive Director of the Food Standards Agency of 7th August 2009. http://www.food.gov.uk/news/newsarchive/2009/aug/letter. Visited on 18/08/2009.

[208] M Kristensen, LF Østergaard, U Halekoh, H Jørgensen, C Lauridsen, K Brandt, S Bügel. 2008. "Effect of plant cultivation methods on content of major and trace elements in foodstuffs and retention in rats" *Journal of the Science of Food and Agriculture* 88(12), 2161-2172.

[209] C Caris-Veyrat, MJ Amiot,V Tissandier, y cols. 2004. "Influence of organic versus conventional agricultural practice on the antioxidant micro-constituent content of tomatoes and derived purées; consequences on antioxidant plasma status in humans". *Journal of Agricultural and Food Chemistry* 52, 6503-6509.

[210] DM Barrett, C Weakley, JV Diaz, M Watnik. 2008. "Qualitative and nutritional differences in processing tomatoes grown under commercial organic and conventional production systems". *Journal of Food Science* 72, C441-C451.

[211] P Collier. 2008. "The politics of hunger". *Foreign Affairs* 87(6), 67-30.

[212] European Group on Ethics. 2008. *Ethics of modern developments in agriculture technologies*. http://ec.europa.eu/european_group_ethics/docs/agriculture_technologies_ethics.pdf Visited on 22/10/2009.

[213] Regulation 1829/2003/EC and Regulation 1830/2003/EC of 18th September of 2003. Official Journal of the European Union of 18th October 2003, L268/24-28.

214 M Hickman. 2009. "Big stores counting the cost of ban on GM food". *The Independent,* 1st September 2009. http://www.independent.co.uk/environment/green-living/big-stores-counting-the-cost-of-ban-on-gm-food-1779870.html. Visited on 2/09/2009.

215 P Barato. Summer Courses at El Escorial, August 2009. Fundación Antama: http://www.fundacion-antama.org/noticia/el-bloqueo-europeo-de-los-omgs-dejar-los-agricultores-comunitarios-fuera-del-mercado. Visited on 1/09/2009.

216 LH Aramyan, CPA van Wagenberg, GBC Backus. *EU Policy on GM soy – tolerance threshold and asynchronic approval*. Informe 2009-052. Proyecto 31582, LEI Wageningen UR, La Haya. Mayo 2009. http://edepot.wur.nl/7856 Visited on 22/10/2009.

217 European Commission, Directorate-General for Agriculture and Rural Development. 2007. *Economic impact of unapproved GMOs on EU feed imports and livestock production*. Brussels. http://ec.europa.eu/agriculture/envir/gmo/economic_impactGMOs_en.pdf Visited on 22/10/2009.

218 News item published by EuroCarne Digital of 24th August 2009. http://www.eurocarne.com/index.php?/noticias/ultimas/ficha_noticia.php?codigo=14490&fechanoticia=20090824. Visited on 31/08/2009.

219 Fundación Antama: http://www.fundacionantama.org/noticia/ministros-y-agricultores-britanicos-apuestan-por-el-aumento-de-importancion-de-omgs. Visited on 1/09/2009.

220 R Paarlberg. 2008. Op. cit., pg. 3.

221 R Paarlberg. 2008. Op. cit., pg. 1-20.

222 Quoted in "Las malas hierbas, la principal amenaza de los agricultores". Fundación Antama. 2009. http://www.fundacion-antama.org/noticia/las-malas-hierbas-la-principal-amenaza-de-los-agricultores. Visited on 4/09/2009.

223 Nuffield Council on Bioethics. 2004. *The use of genetically modified crops in developing countries. A follow-up discussion paper.* Latimer Trend & Co., pg. 48. http://www.nuffieldbioethics.org/go/ourwork/gmcrops/publication_313.html. Visited on 11/10/2009.

224 Nuffield Council on Bioethics. 2004. Op. cit., pg. xvi.

225 United Nations. 2001. *Human Development Report 2001. Making New Technologies Work For Human Development*. Pg. 62. http://www.undp.org/en/reports/global/hdr2001/chapters/spanish. Visited on 11/10/2009.

226 FAO. 2004. Report available at: http://www.fao.org/docrep/006/Y5160s/Y5160s00.HTM. Visited on 22/10/2009.

227 United Nations. 2001 Human Development Report. Op. cit.

[228] This is one of the main theses of R Paarlberg's already mentioned work, *Starved for science*.

[229] Can be consulted at: http://www.grain.org/m/?id=26# Visited on 22/10/2009.

[230] D Taverne. 2007. "The real GM food scandal". *Prospect,* November 2007, 24-27.

[231] R Paarlberg, 2008. Op. cit. pg. 179-195.

[232] C Juma, I Serageldin. 2007. *Freedom to innovate. Biotechnology in Africa's development*. African Union.
http://www.nepadst.org/doclibrary/pdfs/biotech_africarep_2007.pdf. Visited on 11/10/2009.

[233] Editorial "A fruitless campaign". 2008. *Nature* 456, pg. 421-422.

[234] R Paarlberg, 2008. Op. cit., pg. 106-110.

[235] R Paarlberg, 2008. Op. cit., pg. 124-134.

[236] Address of the FAO Director before the Italian Parliament on 17th September 2008 concerning the crisis caused by the food price increase and its impact of world food security. Web page:
http://www.fao.org/newsroom/es/news/2008/1000922/index.html. Visited on 22/10/2009.

[237] JI Cohen. 2005. "Poorer nations turn to publicly developed GM crops". *Nature Biotechnology* 23, 27-33.

[238] K Ammann. 2002. "Thoughts about the future of agriculture: science and fiction in the risk assessment debate". In: *Sustainable food security for all by 2020: Proceedings of an International Conference*. International Food Policy Research Institute. Washington.
United Nations. 2001. Human *Development Report* 2001. Op. cit.

[239] Kenong Xu, Xia Xu, Takeshi Fukao, Patrick Canlas, Reycel Maghirang-Rodriguez, Sigrid Heuer, Abdelbagi M. Ismail, Julia Bailey-Serres, Pamela C. Ronald, David J. Mackill. "Sub1A is an ethylene-response-factor-like gene that confers submergence tolerance to rice" 2006. *Nature* 442, 705-712.

[240] FAO Director's address to the Italian Parliament cited above.

[241] "Un corazón contra el odio". Article published in the XLSemanal on 30th August 2009. The film *The Heart of Jenin* was awarded the prize for the best documentary at the 2008 Valladolid Film Festival.