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Biotechnologies for Agricultural Development

Contents

Introduction

In our modern day and age of science, technology and innovation almost everyone has heard the term "Biotechnology" at least once, and if they didn't, they surely heard of something that comprises or is related to it. So, what is it?

According to the Oxford Dictionary, term "Biotechnology" stands for "The exploitation of biological processes for industrial and other purposes, especially the genetic manipulation of microorganisms for the production of antibiotics, hormones, etc."[1] – which basically means that any human activity and production that has something to do with biological matter and nature is to be considered utilizing biotechnology of some sort. In fact, one can say that human utilization of biotechnology predates even the first civilizations, given that agricultural plant cultivation and animal husbandry do fit into the broad definition of the term.

Nowadays biotechnology encompasses a huge variety of scientific and bioengineering sub-fields of research and implementation from brewing to ecology, from agronomy to pharmaceutics. Modern biotechnology provides breakthrough products and technologies to combat rare diseases, reduce our environmental footprint, feed the hungry, use less and cleaner energy and have safer, cleaner and more efficient industrial manufacturing processes.

However not everything is as bright and innocent as it appears to be. On the one hand, for example, biotechnological processes and techniques present solutions to overcoming poor crop yields, while reducing crop losses due to pests and drought (currently about 30 percent of crops are lost to pests).[2] On the other hand, according to a recent report[3] from the Food and Agriculture Organization agriculture committee, if biotechnology is linked to intensive farming, this can lead to loss of biodiversity and soil degradation. There's also a matter of special significance to the developing countries – a threat of becoming over-dependent on foreign expertise and/or products at the expense of local production capacity using the traditional techniques and resources.

Another big concern came with the rise of genetic engineering. It is still debated whether gene manipulation and genetic engineering are to be considered part of biotechnology, but they will be mentioned in this report nonetheless due to their controversial nature and significance.

Today it is possible to identify a gene,

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1 Oxford Dictionary [Electronic resource] – Mode of access : https://en.oxforddictionaries.com/definition/biotechnology

2 Sallam M.N. INSECT DAMAGE: Damage on Post-harvest [Electronic resource] / M.N. Sallam. – International Centre of Insect Physiology and Ecology. – 2000. – 38p. – Mode of access : http://www.fao.org/3/a-av013e.pdf

3 Dargie J. D. Ten Lessons from Biotechnology Experiences in Crops, Livestock and Fish for Smallholders in Developing Countries [Electronic resource] / J. D. Dargie, J. Ruane, A. Sonnino ; Food and Agriculture Organization of the United Nations. – 2013. – 8p. – Mode of access : http://www.fao.org/docrep/019/as351e/as351e.pdf

to isolate it, cut it, insert it and transfer it. This is what we understand under genetic manipulation or genetic engineering. Genetic engineering has made it possible to improve our understanding of the living organism and to use this knowledge in life and activities of human beings - for example, in food, agricultural production, forestry, animal rearing, horticulture, public health, vaccines, reproduction, the production of energy and combatting pollution.

However, there are great ecological and ethical concerns when it comes to Gene manipulation and Genetically Modified Organisms – GMO for short. One of the risks is that the GMO will interfere with the environment[4]: pollen carried on the wind could pollinate wild varieties of the modified plant, producing hybrids with unknown characteristics. Weed- and Pest-resistant GMOs may lead to destabilization of whole ecosystems. Then there are also concerns about the potential health effects of existing GMO on human beings – and although there still haven't been any proven cases of direct harm caused by existing and approved genetically modified produce, the issue remains open and poses a threat not so much in physical, but in ethical sense.

It also goes without saying that human gene manipulation and genetic engineering is discouraged and heavily regulated by the majority of governments on Earth. Several governments have already acted to impose limits on the use of genetic engineering on humans, particularly where the changes will be passed on to an individual's children. And when UNESCO's International Bioethics Committee drafted a Universal Declaration on the Human Genome and Human Rights[5], it was adopted by all 186 Member States (11 November 1997) and subsequently by the UN General Assembly (9 December 1998).

4 Glass E. The Environmental Impact of GMOs [Electronic resource] / Emily Glass // OneGreenPlanet. – 2013. – August 2. – Mode of access : http://www.onegreen-planet.org/animalsandnature/the-envi-ronmental-impact-of-gmos/

5 Universal Declaration on the Human Genome and Human Rights [Electronic resource] / The United Nations. – Mode of access : http://www.unesco.org/new/en/social-and-human-sciences/themes/bioethics/human-genome-and-human-rights/

Chapter 1. Origins and history of Biotechnology

Basic principles of biotechnology were used by humankind for more than ten thousand years with selective breeding of crops and cattle – though very basic and primitive – and using natural byproducts as craftsmanship resources.

Still, if we refer to the modern and more specific understanding of biotechnology as the application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services, we can still trace such practices back to as far as the Ancient Mesopotamia and Egypt from where, for example, came the first documented cases of consuming and – more importantly for us – producing beer[6], which is made with the help of fermentation – a process where biological reactions of yeast, hops and certain cereal grasses like barley serve the purpose of enriching the beverage and making it alcoholic.

Being one of the first examples of utilizing biotechnology in goods' production it is only natural that brewing became the first subject of scientific study in the field of biotechnological studies. This field called zymotechnology – from greek Ζύμωση[Zimosi], which means "fermentation" – arose in Germany in late XIX century in response to the increasing demand for beer and it being an important industrial commodity of the state – alcohol brewing was one of the largest sources of income for the government contributing as much to the national GDP as steel manufacturing. Numerous scientific institutes were created with only one purpose – to research ways of more efficient and extensive brewing of beer, Karlsberg institute being one of the most prominent.

This might sound like a bit of a niche and non-significant field of study that has little to do with modern science, but in reality these "beer institutes" have laid a groundwork for a deeper comprehension of the possibilities and opportunities mother nature provides for production and engineering – and that groundwork paid off during WWI, when zymotechnology blossomed and expanded its borders and horizons, becoming so much more than just a science about brewing: on both sides of the frontlines scientists and engineers made incredible inventions and breakthroughs in order to maintain a steady flow of supplies and rations to the frontlines and the home front likewise – substitutes for rare technical liquids, machine oils, fodder for cattle and horses, new animal husbandry techniques to meet the lack of working hands and fading resources as the war raged on, synthesizing rare chemicals from common plant life – problem of the British deficit of Acetone, for example, was solved by a Russian scientist who devised a process of creating it from maize cultures.

Soon the practical application of fermentation grew so much past its traditional bounds of brewing alcohol that the very name of the field – "Zymotechnology" – became obsolete. The Hungarian en-

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6 Eßlinger H. M. Handbook of Brewing: Processes, Technology, Markets [Electronic resource] / H. M. Eßlinger. – Weinheim : WILEY-VCH Verlag GmbH & Co. KGaA, 2009. – 42p. – Mode of access : https://application.wiley-vch.de/books/sample/3527316744_c01.pdf

trepreneur Károly Ereky coined the word "Biotechnology" during 1919 to describe a technology based on converting raw materials into a more useful product, and the term soon caught on.

This catchword spread quickly, as "biotechnology" entered German dictionaries and was taken up abroad by business-hungry private consultancies as far away as the United States. In Chicago, for example, the coming of prohibition at the end of World War I encouraged biological industries to create opportunities for new fermentation products, in particular a market for nonalcoholic drinks. Emil Siebel, the son of the founder of the Zymotechnic Institute, broke away from his father's company to establish his own called the "Bureau of Biotechnology", which specifically offered expertise in fermented nonalcoholic drinks.

The belief that the needs of an industrial society could be met by fermenting agricultural waste was an important ingredient of the "chemurgic movement" – a global trend of utilizing agricultural produce to create industrial goods. Fermentation-based processes generated products of ever-growing utility with penicillin becoming the most notable by the 1940s. While it was discovered in England, it was mass-produced industrially in the U.S. using a deep fermentation process originally developed in Peoria, Illinois. Enormous profits and public expectations penicillin evoked caused a radical shift in the standing of the pharmaceutical industry. Doctors used the phrase "miracle drug", and the historian of its wartime use, David Adams, has suggested that to the public penicillin represented the perfect health that went together with the car and the perfect house of wartime "American Dream" advertising. Beginning in the 1950s, fermentation technology also became advanced enough to produce steroids on industrially significant scales.

Even greater expectations of biotechnology were raised during the 1960s by a process that grew single-cell protein. With rise and acknowledgement of the so-called protein gap that threatened world hunger, producing food locally by growing it from industrial waste seemed to offer a solution. It was the possibilities of growing edible microorganisms on oil that captured the imagination of scientists, politicians, and businessmen. The trend was quickly picked up by British Petroleum who opened in 1962 their first experimental plant in Southern France that had oil by-product-grown proteins as their produce.

As there was no well-accepted term to describe the new foods, in 1966 the term "single-cell protein" (SCP) was coined at MIT to provide an acceptable and exciting new title, avoiding the unpleasant connotations of microbial or bacterial. The "food-from-oil" idea quickly became popular all over the world with a whole variety of plants producing yeast fed on n-paraffins being built everywhere – especially in the Soviet Union, where 2 large Protein-Vitamin Concentrate (БВК – Белково-Витаминный концентрат) plants were constructed next to their oil refineries in

Kstovo and Kirishi in 1973-1974.[7]

By the late 1970s, however, the enthusiasm over the SCP was all but gone, with cultural climate changes, skyrocketing oil prices that quintupled in less than 5 years and market shift of the product interest from humans to animals: even though SCPs were originally conceived and created as a means to combat hunger in developing countries, the product was instead launched as an animal food for the developed world. The rapidly rising demand for animal fodder made that market appear more economically attractive. The ultimate downfall of the SCP project, however, came from public resistance – people just couldn't get past the fact of the "unnatural" oil origin of the food which led to the end of the SCP project as an attempt to solve world hunger.

Biotechnology seemed to be the solution for major social problems, including world hunger and energy crises. In the 1960s, radical measures would be needed to meet world starvation[8], and biotechnology seemed to provide an answer. However, the solutions proved to be too expensive and socially unacceptable, and solving world hunger through SCP food was dismissed. In the 1970s, the food crisis was succeeded by the energy crisis, and here too, biotechnology seemed to provide an answer. But once again, costs proved prohibitive as oil prices slumped in the 1980s. Thus, in practice, the implications of biotechnology were not fully realized in these situations. But this would soon change with the rise of genetic engineering.

Despite the structure of DNA being discovered rather early, in 1953 by Watson and Crick, any practical application of genetic science was all but fruitless until 1973 when the US inventors and scientists Stanley N. Cohen and Herbert W. Boyer introduced a method of creating recombinant DNA molecules, which basically allowed the extraction of any section of DNA string and inserting it anywhere else. This approach could, in principle, enable bacteria to adopt the genes and produce proteins of other organisms, including humans[9].

Still, even prior to that gene manipulation drew a lot of enthusiasts, who used the new-found knowledge to advance science: In December 1967, the first heart transplant by Christian Barnard reminded the public that the physical identity of a person was becoming increasingly problematic. During the same month, Arthur Kornberg announced that he had managed to biochemically replicate a viral gene. "Life had been synthesized", declared the

7 Shabad T. Soviet Plant to Convert Oil to Protein for Feed [Electronic resource] / Theodore Shabad // The New York Times. – 1973. – November 10. – Mode of access : http://www.nytimes.com/1973/11/10/archives/soviet-plant-to-convert-oil-to-protein-for-feed-use-of-yeast.html?_r=0

8 Roser M. Famines [Electronic resource] / Max Roser // OurWorldInData.org. – 2016. – Mode of access : https://ourworldindata.org/famines

9 Kuroiwa I. Production Networks and Industrial Clusters: Integrating Economies in Southeast Asia / Ikuo Kuroiwa, Toh Mun Heng ; ISEAS / IDE-JETRO, 2008. – p. 167

head of the National Institutes of Health.[10]

The sheer potential of this young field of biological science thrusted it into the centre of public attention, as world scientists, politicians and media became more and more interested in its ground-breaking achievements – revolutionary, miraculous and horrifying at the same time.

Responses to scientific achievements were colored by cultural skepticism. Scientists and their expertise were looked upon with suspicion. In 1968, an immensely popular work, “The Biological Time Bomb”, was written by the British journalist Gordon Rattray Taylor. The author’s preface saw Kornberg’s discovery of replicating a viral gene as a route to lethal doomsday bugs. The publisher’s advertisement sheet for the book warned that within ten years, “You may marry a semi-artificial man or woman... choose your children’s sex... tune out pain... change your memories... and live to be 150 – if the scientific revolution doesn’t destroy us first”.

In response to these public concerns, scientists, businessmen, and governments increasingly linked the power of recombinant DNA to the immensely practical functions that biotechnology promised. While in the 1960s “genetic engineering” described eugenics and work involving the manipulation of the human genome, more and more focus was set on research that would involve microbes instead in order to find ways to cure living people and changing their phenotype, not genotype – changing how they look and appear physically, not changing and (potentially) harming their genome.

With the discovery of recombinant DNA by Cohen and Boyer in 1973, the idea that genetic engineering would have major physical and social consequences was born. In July 1974, a group of eminent molecular biologists headed by Paul Berg wrote to Science journal suggesting that the consequences of this work were so potentially destructive that there should be a pause until its implications had been thought through[11]. This suggestion was explored at a meeting in February 1975 at California’s Monterey Peninsula, in Asilomar. Its historic outcome was an unprecedented call for a halt in research until it could be regulated in such a way that the public need not be anxious, and it led to a 16-month moratorium until National Institutes of Health guidelines were established.

The radical shift in the connotation of “genetic engineering” from an emphasis on the inherited characteristics of people to the commercial production of proteins and therapeutic drugs was nurtured by Joshua Lederberg. His broad concerns since the 1960s had been stimulated by enthusiasm for science and its potential medical benefits. Countering calls for strict regulation, he expressed a vision of potential utility. Against a belief that new techniques would entail unmentionable and uncontrollable consequences for humanity and the environment, a growing consensus on the economic value of recombinant DNA emerged.

With ancestral roots in industrial mi-

10 Bud R. The Uses of Life: A History of Biotechnology / Robert Bud. – Cambridge University Press, 1994. – p. 165

11 Bud R. The Uses of Life: A History of Biotechnology / Robert Bud. – Cambridge University Press, 1994. – p. 167

crobiology that date back centuries, the new biotechnological industry grew rapidly since the middle of 1970s. Each new scientific advance became a media event designed to capture investment confidence and public support. Although market expectations and social benefits of new products were frequently overstated, many people were prepared to see genetic engineering as the next great advance in technological progress. By the 1980s, biotechnology characterized a nascent real industry, providing titles for emerging trade organizations such as the Biotechnology Industry Organization.

Genetic engineering also reached the agricultural front as well. There was tremendous progress since the market introduction of the genetically engineered Flavr Savr tomato in 1994 – first genetically modified food ever to be granted a license for human consumption and grown commercially. It was designed to be more rot-resistant and to soften less than its conventional counterpart and was sold from 1994 to 1997 when the producing company went bankrupt due to the lack of business experience of its founder and rather high mounting costs for GM tomatoes' production.

At the same time another company – in Britain this time around – started producing GM tomato paste using techniques similar to the above-mentioned, which allowed much cheaper production. This paste was sold freely throughout Britain's supermarkets with "Genetically Modified" labels on packages during the period of 1996-1999 and at some point it even outsold the conventional analogues.

Everything changed in 1998 when media exploded after the high-profile event that later came to be known by the name of "Pusztai affair". On 22nd of June, 1998 protein scientist Árpád Pusztai from Rowett Research Institute went public about his unpublished research on genetically-modified potatoes during an interview on Granada Television's current affairs programme "World in Action", in which he stated that he had "concerns that some of the testing techniques are not up to what we thought it was necessary to do, and therefore we should have more testing". When asked why he felt concerned, he said "it was because we had done some experiments which made us feel concerned" and discussed his results in general terms. Among other things he mentioned that the rats in his experiments suffered stunted growth and had suppressed immune systems and that more safety research was required. Pusztai later said that at the time of the interview he was not sure if he should reveal results from experiments that had not been completed and did not think the programme would be hostile toward genetically modified food. He estimated that the experiments were 99 percent complete when the interview was conducted.

The reaction that followed was explosive, with media all over the world slandering GM foods and branding them as unsafe and risky, while scientific society remained in confusion on how to react to this incident. Numerous audits were conducted by several independent and rather respectable scientific organizations, all of which proved Pusztai's actions to be unprofessional, his experiments poorly designed and yielding very incomplete data with a huge margin of error. A lot of his colleagues criticized the scientist for going public about his founds on popular media prior to completing all the tests and publishing his work.

The study was eventually published, triggering further controversy. Pusztai was suspended and misconduct procedures were used to seize his data and ban him from speaking publicly. The Institute did not renew his annual contract, and to this day the scientist remains a controversial figure in the field with some blaming him for being tilting the public opinion against the GMO and others praising him for attracting the world's attention to the utmost importance of strict safety procedures and audits when it comes to developing new GM products.[12]

Although in general the incident worked more in favour of the scientific progress, triggering the first audit of genetically modified product safety and stressing the need for regulation of GM food safety, the way it was conducted and the large-scale unsupervised involvement of mass media led to creation of a fixed image of GM foods as something inherently bad and unhealthy, with numerous pseudo-researches conducted or paid by popular tabloids and their peers that confirm the above-mentioned statement and make a boogieman out of GMO till present day, slandering the whole industry and reinforcing the cultural skepticism surrounding the issue.

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12 Randerson J. Arpad Pusztai: Biological divide [Electronic resource] / James Randerson // The Guardian. – 2008. – January 15. – Mode of access : https://www.theguardian.com/education/2008/jan/15/academicexperts.highereducationprofile

Chapter 2. Modern agricultural application of Biotechnology

Currently all biotechnologies in use in agricultural field can be narrowed down to a following list:

- genetically modified crops resistant to pests, viruses, drought, etc.
- genetically modified crops that ripen slowly during transportation before display
- use of organic material to produce biodegradable plastics, fuel, fertilizer
- in vitro fertilization of farm animals using selected sperm and eggs
- use of recombinant growth hormone to increase milk and meat production
- genetically modified crops with better nutritional qualities
- fish farming (aquaculture)
- seaweed farming to produce fatty acids, etc.
- production of adhesives from mussels and barnacles
- use of enzymes from thermophile bacteria (usually living in dark, sulphurous, hot environments in the deep sea) for waste removal, or in sequencing DNA
- production of tree clones from tissue culture
- production of wood pulp for the paper industry

Crop biotechnologies have developed incrementally over the past century, but progress has accelerated greatly over the last two decades leading to many important scientific achievements and impressive technological advances. A wide range of crop biotechnologies is available and some are increasingly used in developing countries, especially tissue culture-based techniques (such as micro-propagation), mutagenesis, interspecific or intergeneric hybridization, genetic modification, marker-assisted selection (MAS), disease diagnostics and bioprotection, and biofertilization.

Despite some controversies and ethical concerns, most biotechnologies pose no ethical or social problems and are useful – for example by using micro-propagation one can make thousands of identical plants and can supply agriculture with potatoes, strawberries and so on all year round. What is more, they are virus-free, so production is more efficient – and without the usage of any genetic engineering whatsoever. All that is done is exploitation of a natural property of plants' cells to produce plants that are identical to the one the cell was taken from. There are thousands of millions of these 'test tube plants' or 'vitroplants' produced in the world – the flower market is especially full of them. Even poor countries have become major producers of vitroplants – thanks to this technique Kenya is now a major exporter of flowers[13].

Biotechnologies such as cryopreservation, artificial seed production, somatic embryogenesis, and other forms of in vitro cell or tissue culture are also

13 Rikken M. The global competitiveness of the Kenyan flower industry [Electronic resource] / Milco Rikken // ProVerde. – 2011. – Mode of access : http://www.kenyaflowercouncil.org/pdf/VC5%20Global%20Competitiveness%20Kenyan%20Flower%20Industry%20-%20ProVerde.pdf

extensively used for the conservation of genetic resources for food and agriculture in developing countries.

The uptake of biotechnologies in developing countries is increasing gradually but remains patchy. Many biotechnological advances were made in industrialized countries in the private sector, leading to development of proprietary technologies that are often unavailable to scientists in developing countries. Farmers in developing countries, especially small farmers, cultivate crops and face problems that are particular to their cultural and environmental conditions, and have often limited purchasing power to access proprietary technologies. The spillover of research results obtained in industrialized countries by the private sector has therefore had only a limited impact on the livelihoods of subsistence farmers in developing countries. In fact, the most enduring successes to date have come from indigenous public-sector crop research programmes addressing farmer-relevant problems.

Developing countries can indeed benefit from implementing certain biotechnology techniques and develop certain biotechnologies without the need for high-tech facilities – manufacturing of nitrogen-fixing biological fertilizers being one of those.

But FAO has also expressed reservations about the value of biotechnologies for developing countries, unless they are linked to more sustainable, organic farming techniques[14]. Organic farming – which is compatible with some biotechnological innovations, such as biological fertilizers and pest-resistant crops – has usually been considered uneconomical for developing countries. But, according to FAO report on the topic, organic agriculture can contribute to local food security in several ways: organic farmers do not incur high initial expenses so less money is borrowed; synthetic inputs, unaffordable to an increasing number of resource-poor farmers due to decreased subsidies and the need for foreign currency, are not used; Organic soil improvement may be the only economically sound system for resource-poor, small-scale farmers. Labour-intensive organic farming also provides employment in rural areas where human resources are readily available, while encouraging biodiversity and the sustainable restoration of soil as a living environment.

Even when there has been strong development of biotechnologies within the public sector in developing countries, they have not always been directed towards – or made available for – improving smallholder livelihoods. In fact, an inclusive process of decision-making about the allocation of resources for the development of appropriate crop

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14 Dargie J. D. Ten Lessons from Biotechnology Experiences in Crops, Livestock and Fish for Smallholders in Developing Countries [Electronic resource] / J. D. Dargie, J. Ruane, A. Sonnino ; Food and Agriculture Organization of the United Nations. – 2013. – 8p. – Mode of access : http://www.fao.org/docrep/019/as351e/as351e.pdf

biotechnologies was rarely adopted, undermining the successful development of crop biotechnologies. In some cases, even though the technology was sound and the products were potentially beneficial to farmers, there was limited or no adoption due to often-predictable infrastructure or market deficiencies. A promising approach to address such problems is farmer participatory research but this must be coupled with measures to address a wide range of cross-sectoral issues from extension services to seed multiplication programmes.

Nonetheless, elsewhere in the world farmers have already widely adopted GM technology. Between 1996 and 2011, the total surface area of land cultivated with GM crops had increased by a factor of 94, from 17,000 km^2 to 1,600,000 km^2. 10% of the world's crop lands were planted with GM crops in 2010. As of 2011, 11 different transgenic crops were grown commercially on 160 million hectares in 29 countries such as the USA, Brazil, Argentina, India, Canada, China, Paraguay, Pakistan, South Africa, Uruguay, Bolivia, Australia, Philippines, Myanmar, Burkina Faso, Mexico and Spain.[15]

Moreover, the "State of Food and Agriculture 2003–2004" report[16] published by FAO clearly states the importance of transgenics research with focus on supporting the poor and providing the means for the developing countries to get cheap access to biotechnologies, as well as endorses both public and private sector to invest into GM research with focus on sustaining the developing countries and providing them with the means to overcome hunger and other related problems.

It is also worth mentioning that a new discipline called cellular agriculture arose lately, its primary task being the creation of foodstuffs and other products in vitro – in a vat – potentially speeding up the process of producing food and crops spectacularly and bypassing some serious ethical concerns when it comes to modern industrial animal husbandry, for example. First successful tests have already been carried out, and on 5th of August, 2013 first ever successful public demonstration occurred in London, England at a news conference.[17]

15 Clive J. Global Status of Commercialized Biotech/GM Crops: 2011 [Electronic resource] / James Clive // Ithaca, NY : ISAAA, 2011. – Mode of access : http://www.isaaa.org/resources/publications/briefs/43/executivesummary/default.asp

16 The state of food and agriculture 2003-2004 [Electronic resource] / Food and Agriculture Organization of the United Nations. – 2004. – Mode of access : http://www.fao.org/docrep/006/Y5160E/y5160e00.htm

17 World's first lab-grown burger is eaten in London [Electronic resource] / BBC News. – 2013. – August 5. – Mode of access : http://www.bbc.com/news/science-environment-23576143

Chapter 3. Possible problems and concerns of the extensive use of Biotechnology

Despite the clearly beneficial role of biotechnology in improving the living standards and quality of life for the humanity, there are still some concerns and potential threats that the extensive use of said technologies might pose to the environment and the humanity itself.

There's no doubt that introduction of some biotechnological products was clearly beneficial to the developing countries, like drought-resistant crops in Sahel region or higher yield crops in India that quadrupled the modern harvests in comparison to those at the time of Indian independence. Still, FAO has expressed reservations about the value of biotechnologies for developing countries, unless they are linked to more sustainable, organic farming techniques as there is a danger of over-dependence on outside expertise and/or products at the expense of local capacity building and development of produce that uses traditional knowledge, skills and natural resources.

According to a recent report from FAO agriculture committee,[18] if biotechnology is linked to intensive farming, it can lead to loss of biodiversity and soil degradation. Indeed, introducing strong, genetically modified organisms or organisms enhanced or advantageous in any other way into a foreign ecosystem en masse can potentially lead to its destruction due to disturbance in the food chain in the same manner ecosystems of Australia and Russia were harmed by introducing foreign life forms on a large scale without proper precautions in well-known incidents with Old World animal infestations in the former and cow parsenip plant plague in the Central regions of the latter.

It is even more of an issue, in fact, as one of the risks is that the GMO will interfere with the environment directly, as pollen carried on the wind could pollinate wild varieties of the modified plant, producing hybrids with unknown characteristics. Of course, pollen only travels from 100 metres to one kilometre from its source[19] and thus can be regulated – the transgenic variety has to be separated by one kilometre from other varieties. Such risks should be taken into consideration.

As for the health safety of GMO, there is a scientific consensus[20] that currently available food derived from GM crops poses no greater risk to human health than conventional food, but that each GM

18 Dargie J. D. Ten Lessons from Biotechnology Experiences in Crops, Livestock and Fish for Smallholders in Developing Countries [Electronic resource] / J. D. Dargie, J. Ruane, A. Sonnino ; Food and Agriculture Organization of the United Nations. – 2013. – 8p. – Mode of access : http://www.fao.org/docrep/019/as351e/as351e.pdf

19 All About Pollen [Electronic resource] / Seeds of diversity. – Mode of access : http://www.seeds.ca/pollination/pollen-and-flowers/pollen

20 Domingo J.L. A literature review on the safety assessment of genetically modified plants / J.L. Domingo, J. Gine Bordonaba // Environment International. – 2011. – issue 37. – p. 735

food needs to be tested on a case-by-case basis before introduction. Nonetheless, members of the public are much less likely than scientists to perceive GM foods as safe. The legal and regulatory status of GM foods varies by country, with some nations banning or restricting them, and others permitting them with widely differing degrees of regulation.

The basic concepts for the safety assessment of foods derived from GMOs have been developed in close collaboration under the auspices of the Organization for Economic Co-operation and Development (OECD), the United Nations' World Health Organization (WHO) and Food and Agricultural Organization (FAO). A first joint FAO/WHO consultation in 1990 resulted in the publication of the report 'Strategies for Assessing the Safety of Foods Produced by Biotechnology' [21] in 1991. Building on that, an international consensus was reached by the OECD's Group of National Experts on Safety in Biotechnology, for assessing biotechnology in general, including field testing GM crops. That Group met again in Bergen, Norway in 1992 and reached consensus on principles for evaluating the safety of GM food; its report, 'Safety evaluation of foods derived by modern technology – concepts and principles'[22] was published in 1993. That report recommends conducting the safety assessment of GM food on a case-by-case basis through comparison to an existing food with a long history of safe use. This basic concept has been refined in subsequent workshops and consultations organized by the OECD, WHO, and FAO, and the OECD in particular has taken the lead in acquiring data and developing standards for conventional foods to be used in assessing substantial equivalence. In 2003 the Codex Alimentarius (Latin for "Food Code") Commission of the FAO/WHO adopted a set of "Principles and Guidelines on foods derived from biotechnology" to help countries coordinate and standardize regulation of GM food to help ensure public safety and facilitate international trade and updated its guidelines for import and export of food in 2004.

Furthermore, the United Nations Convention on Biological Diversity[23], signed on the 5th of June, 1992 by every single member state and ratified by everyone except the USA has several articles devoted to preserving the natural diversity of life on the planet in spite of utilization if genetically modified organisms and other forms of biotechnology.

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21 Strategies for assessing the safety of foods produced by biotechnology [Electronic resource] / Joint Food and Agriculture Organization of the United Nations and World Health Organization Consultation. – Geneva. – 1991. – 28p. – Mode of access : http://library.health.go.ug/download/file/fid/790

22 Safety Evaluation of Foods Derived by Modern Biotechnology: Concepts and Principles [Electronic resource] / Organisation for Economic Co-operation and Development. – 1993. – Mode of access : http://dbtbiosafety.nic.in/guideline/OACD/Concepts_and_Principles_1993.pdf

23 Convention on Biological Diversity [Electronic resource] / The United Nations. – Mode of access : https://www.cbd.int/convention/text

Conclusion

We live in a changing world that faces many problems - yet for the first time in human history the humankind has actually come together to make an attempt to solve those problems such as world hunger, poverty, violence and many others. It is clear though, that one cannot do this by sheer will or by using conventional means – one should think outside of the box, innovate, take risks – yet at the same time remain fully responsible for one's actions and cautious of the potential harm one can do to others and our planet in general.

Biotechnology provides solutions to those problems – yet one should take care as any medicine can easily become a poison in wrong or inept hands. It is still a matter of discussion whether we need the GM crops or any genetically modified organisms at all, whether it is ethical to grow meat and other things in vats, whether there are any other ways to solve the issues at hand – but one thing is certain, which is that humanity is making active steps in search for a solution, and this is already half a job done.

In developing countries, there is a need for continued focus on optimizing agricultural output in conjunction with conserving the natural resources base via improved crops and crop management systems. The implications of climate change make it necessary to integrate considerations regarding adaptation, uncertainty, vulnerability and resilience into agricultural research programmes and strategies. The various biotechnologies available have the potential to play a significant role in achieving these aims.

Still, we need to closely regulate and monitor their usage and research and ensure that no misuse of biotechnology – be it accidental or deliberate – ever occurs. They say that "The progress waits for no-one", yet it is in our hands to define what that progress will actually be like and what future awaits us tomorrow.

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Контакты

Секретариат

Адрес:

119454, Москва, Проспект Вернадского,
76, Спортцентр МГИМО, комната №36

Телефон / факс:

+7 (495) 434-07-10
+7 (495) 434-30-11

vk.com/mimun2017

@mimun2017

fb.com/awesome.mimun

@mimun2017

secretariat@modelun.ru

modelun.ru